A GUIDE

TO THE

DETERMINATION OF ROCKS;

BEING AN INTRODUCTION TO LITHOLOGY.

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TRANSLATED FROM THE FRENCH

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TRANSLATOR'S PREFACE.

The following pages have been translated with a view to supplying students with a desirable supplement to the ordinary academic course of Geology, at the same time affording an easy introduction to the larger treatises on Lithology.

No changes in the plan of the original work have been attempted. The English synonyms for the rock names have been taken mostly from Von Cotta's "Rocks Classified."

The Appendix is a translation from "Cours Elémentaire de Géologie Appliquée," by M. Stanislas Meunier.

The thoroughly practical character of this little treatise, together with the simplicity of the methods of examination, constitute, it is believed, a sufficient claim to the favorable notice of teachers and learners of this department of science.

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DETERMINATION OF ROCKS.

INTRODUCTION.

THE ellipsoidal form of the globe, the temperature of its strata which is greater in proportion to the depth, the incandescence of the lavas thrown from volcanic craters, tend to establish the fundamental fact, that the earth has passed through a condition of igneous fusion. By cooling, a solid crust has been formed whose thickness has increased with the lapse of time.

Among the mineral matters which enter into the composition of this solid crust, a certain number appear in considerable masses, and often with identical or very analogous characters in regions widely separated from each other. It is to these masses that we give the name of ROCKS.

The water which covers three-fourths of the surface of the globe, the air which surrounds it in all directions, the gases and vapors which escape from its depths, merit doubtless the name of elementary parts of the globe; but the determination of these elements of our planet is not conducted by the same process as that for the solid masses or rocks. Of the centre of the earth—the portion enveloped by the exterior solid portion—we know neither the composition nor the physical condition. It is quite certain that its temperature is very high; and it is known that the mean density of this interior portion is higher than that of the surface; but the composition is entirely conjectural.

The rocks called gneiss, composed of crystalline elements disposed in their distinct layers, are regarded as being among those which resulted from the slow cooling of the incandescent globe. Many geologists add also certain fine-grained granites. Rocks of such origin are called *primitive*.

Immediately that the temperature of the surface was sufficiently lowered, the water condensed from the atmosphere, and charged with vapors or gases of different kinds, commenced its chemical rôle as a solvent, and its mechanical rôle as a motor, transporting to points already low, the débris and detritus torn from rocks in the more elevated regions.

This débris is sometimes only the fragments of the former rocks; sand is an example of this kind. Sometimes it is composed of minerals to which the rocks, in decomposing, have contributed only a part of their substance, of which many calcareous rocks furnish examples. Rocks thus formed have oftentimes the appearance of the earth of our fields, and are, in consequence, called *earthy*. They are furthermore termed *sedimentary*, because they have been deposited by water; and *stratified*, because they are disposed in strata or successive parallel layers.

There is a third origin of rocks also very important. From the earliest epochs, there have been produced great rents in the earth's crust, into which have been injected, in a more or less pasty condition, the rocks termed *eruptive*, to which class belong the greater part of the Granites, Porphyries and Trachytes. To this class belong also the volcanic rocks, such as Basalts, Lavas, and the different solid matters which are at the present time thrown from the craters of volcanoes.

Such are the three great orders of rocks, characterized by the following very different relations of position:

(1) Rocks of crystalline structure which have apparently cooled from a fused condition, and of which the oldest are the uppermost and superposed upon the more recent; (2) sedimentary or earthy rocks, of which the first in the order of time are the lowest and are covered by the more modern; (3) eruptive rocks, which are further subdivided into volcanic rocks, and those which in a fused condition have been pushed through the outer covering of rocks already deposited above them. The eruptive rocks have their base in the profound depths of the globe, and connect it, at least at the epoch of their consolidation, to the concentric

envelopes of the interior nucleus, which have been added one after the other, both outside and inside, to the shell of the globe.

But the vapors of the atmosphere immediately after their condensation, the surface-water which penetrates and flows through interstices or crevices of the superficial parts, and, moreover, the emanations from greater depths—all these influences have aided, more or less, to modify the mineralogical character of the rocks. In some, certain elements have been transformed; in others, new elements have been introduced. The movements of the crust have given rise to mechanical phenomena; clays of unknown texture have become schistose or slaty, that is to say divisible, into thin laminæ following planes not parallel to those of stratification; such is the origin of the true slates, as has been demonstrated by the experiments of Sorby, Tyndall and M. Daubrée. Furthermore, sands and fragments of rock have been agglomerated by a cement which has been infiltrated. Sometimes the rock is traversed by distinct veins of foreign material.

We apply the term *metamorphism* more particularly to the modifications produced by the concurrent action of water and mineral vapors which acted at a high temperature, under great pressure, and at the same time with the mechanical movements of the crust. The *Metamorphic Rocks* are those which have been subjected to these modifications. Most geologists place here, mica schists, talcose schists, chlorite schists, clay slates, etc.

Around the crevasses occupied by the eruptive rocks, there is frequently an assemblage of lesser crevices in which, by thermal agencies, exerted in part from below, mineral or metalliferous matters have been deposited. These are *veins*. Finally, at the place of contact of the eruptive rocks and the sedimentary rocks, we see, ordinarily, a mass of mineral matter, whose composition is often analogous to that of the veins, but often also modified by the phenomena of metamorphism.

It is necessary to add to all these rocks, those of organic ori-

gin, such as the carbonaceous fossils, which have been produced from the ancient vegetable world; and which, under different degrees of alteration, are recognized to-day as anthracite coal, bituminous coal, lignite, and peat. To this order belong coprolites and guano.

We admit, therefore, in consideration of their different modes of formation, the following orders of rocks:

A. Rocks crystallized from fused condition.

B. Sedimentary rocks formed from débris of other rocks, whether altered or not; earthy, but rarely crystalline.

C. Rocks of crystalline character in transverse masses: (1) *Eruptive;* (2) *Volcanic.*

D. Sedimentary rocks rendered crystalline: (1) Wholly by metamorphism; (2) In part by infiltration of some cementing material.

E. Rocks in veins or separate masses.

F. Rocks of organic origin.

It is "in place" only and considered with reference to its surroundings, that a rock exhibits all its characters; it is only there that we can study its position and relative age; it is there, finally, that we can draw true conclusions, even regarding its mineral composition. Often we find in some part of a mass, the appearance of a solidified paste of indistinct elements, when a further examination will reveal these elements so far isolated and of such dimensions as to exhibit their distinctive characters.

It is also on the surface that it is necessary to follow these transitions, so numerous, from one rock to another very different in texture.

I have taken the care to note all these changes, so important for geological theories.

The principal object of this book, which I have divided into three parts, is to serve for the practical determination of rocks.

I. In the first part, I have enumerated the principal physical and chemical properties of the mineral species.

II. The second part is devoted to a description of rocks and to the minerals which compose them.

How do we determine rocks to be of the same species? At first sight, the answer is easy enough. They are masses composed of the same mineral species, associated in the same proportion, and, furthermore, having the same texture; but geologists wish to take into account also their mode of formation, which is not easily discovered without a study made "in place." Thus, one has constantly to distinguish granite from gneiss; and it is very difficult to tell in what these two rocks differ in certain cases.

Without knowing precisely the origin, one may notice a difference in constitution of these rocks. Evidently, they have not the same texture: one is composed of elements associated pell-mell; in the other, the elements of the same nature occur in bands or layers. Granite and gneiss have no more the same geological character. But granite has somewhat of the texture of gneiss, as if to show better the affinity of these two species of rock.

Because of their different origins—betrayed in this case by their texture—we shall continue to distinguish gneiss from granite by regarding the mineralogical composition as fundamental.

We call those rocks *simple*, which are composed of elements belonging to the same species; those *compound*, which are composed of elements of different species.

Certain elements always occur in the rock (essential elements). Others appear only accidentally. A great number of the mineral masses, for instance, are composed of Orthoclase, Feldspar and Quartz; these are called *Pegmatites*. In the true *Granites*, to these two materials is added Mica in considerable quantity. Granites differ only from Pegmatites in containing Mica; it is necessary to consider this material as one of their truly *constitutional* and *essential* elements. It seems, reciprocally, that we might call any mineral mass Pegmatite

if it were composed of Feldspar and Quartz, and contained no Mica. Sometimes, nevertheless, the Pegmatites admit of laminæ and large scales of Mica, but always here and there without regularity in the mass, so that the constituent elements are mixed in a manner very homogeneous. Mica would be only mentioned there as an *accidental* element. We distinguish, in general, under the name of *accessory* elements, those which, without being essential, are frequently present.

Among the essential elements of a rock there is generally one which, without always being more abundant than the others, still gives character to the mass by reason of its own prominent physical properties; it may be by a more striking color, a brighter lustre, or by establishing a cleavage in the general texture. Such minerals may be considered as *dominators*. They aid much in determining rocks. It is in this sense that it is necessary to extend, by example, these denominations of rocks — pyroxenic, amphibolic, feldspathic, in which the Pyroxene, the Amphibole and the Feldspar surpass the other elements, not always in ponderable quantity, but in influence on the exterior properties.

In the methodical statement which I have made the object of the second part of this book, I have followed the classification, adopted by M. Daubrée for the collection of the museum of natural history.

III. In the third part, I have sought to present those prominent characteristics which permit the student to reduce at once the number of examinations usually necessary for the determination of a rock. A great number of rocks, in fact, are presented under particular forms which singularly simplify their determination—some better than others—by unanimous consent of all lithologists; only giving a variation of texture a place and special name in the nomenclature.

I have thus obtained the following groups:

1. *Globuliferous* rocks, formed totally, or in part, of globular elements;

2. *Cellular* rocks, full of cells or cavities throughout;

3. *Schistose* rocks, having elements arranged in distinct parallel laminations;

4. *Vitreous* rocks.

I have put upon the same line, always with a view to ready determination, the character — so easy to recognize at first glance — of the homogeneity of the rock, or of its manifest heterogeneous or complex composition.

In addition to the characteristic of texture, I have taken for the last groups, the following:

5. *Simple* rocks in reality or in appearance;

6. *Porphyritic* rocks, composed of a paste of indistinct elements and crystals;

7. *Complex* rocks, formed of discernible elements.

8. *Incoherent* rocks, composed of isolated elements.

Each of these paragraphs is divided into groups, I, II, III, etc.; afterwards successively divided into secondary groups, A, B, C, etc.; these into tertiary groups, (1), (2), (3), etc.; the subdivisions of these last are marked (a), (b), (c), etc.

To obtain these subdivisions, I have made use of the characters most easily recognized, such as the color of the rock, when it is constant in the group and is not found the same in neighboring groups; or such as the crystalline aspect, or earthy character, and fusibility before the blow-pipe. I have frequently, also, employed the character of hardness.

When we wish to determine a rock, we consult first the third part. The first examination suffices to make known the texture, whether globuliferous, cellular, etc. If it is globuliferous, we proceed according to this method, to try its hardness with a steel point. When it is not scratched by this point, a metallic streak left by the steel can be seen; or if it is cut by the point, the fine powder which the cutting produces may be wiped away with the finger, after which the cut itself may be distinctly seen. A rock of group I may be vitreous or compact and dull. If it belongs to group A, it may have a radiated structure. We then

have to choose in subdivision 1, from a small number of species, treated with more ample details in the first part.

Scale of hardness after Mohs; the softest being Talc.

1, Talc; 2, Gypsum or Rock-salt; 3, Calc-Spar; 4, Fluor-Spar; 5, Apatite; 6, Feldspar; 7, Amethyst; 8, Topaz; 9, Sapphire or Corundum; 10, Diamond.

A substance is said to have a hardness of 5.5, (example, Sodalite), when it will scratch Apatite, whose hardness is 5, but when it can be scratched by Feldspar, whose hardness is 6.

The characteristics of fracture are described by the following terms: *Vitreous* fracture yields unequal surface; *conchoidal* fracture produces a curved or shell-like surface; *splintery* fracture presents a surface like that of broken wood; *platy* fracture exhibits plane or nearly plane surfaces; *sparry* fracture exhibits surfaces made up of geometrical planes, as in the surfaces of crystals; *laminated* fracture presents laminæ or thin plates of the mineral. This term is applied when the plates or laminæ are of sensible size; when they are very small the fracture is said to be *foliated.*

The density of a body is the quotient of the weight of that body, by the weight of an equal volume of water. The best process to follow in order to obtain exactly the densities of the pure minerals, is that employed by M. Damour. It consists in replacing one of the plates of a good balance, by a stirrup of wire, furnished below with a little hook, to which is attached, by a very fine wire, a sort of basket formed of a trellis of fine platinum wire. Fill, by means of a pipette, the cup with water recently boiled. Then lower the whole into a vessel of water. Establish an equilibrium. Weigh the body first in air upon the scale which is above the vessel of water; then place it in the basket below, and find its weight immersed in water; the loss of weight which the body experiences, is the weight of the displaced water. It is necessary that, during both of these operations, the basket should remain submerged.

Ordinarily the rock is more or less porous; in this case it is

better to conform to the following process—a little longer, but sure: Reduce the mineral to grains about the size of poppy seed. Wash the grains in such manner as to preserve those which are of uniform size, using distilled water. In place of the platinum basket, suspend to the hook, a little crucible of the same metal, weighing two grammes; balance the crucible while it is immersed in the water, withdraw it and fill it two-thirds full with the grains whose density is sought; immerse it again in the water and weigh it. The difference between the weight of the crucible with the mineral which it contains, and the weight of the crucible alone, is, evidently, the weight of the mineral in the water. Withdraw the crucible and mineral from the water, and place them in a drying oven and drive off the moisture; then again weigh crucible and contents. Subtract this weight from the weight of the crucible alone; the remainder is the weight of the mineral in the air. From this, subtract the weight of the mineral in the water, and we have the weight of the water displaced. Divide the weight of the mineral by the weight of displaced water and we have the density required.

This sketch of the history of rocks would be incomplete without mention of the important part played by Microscopic analysis. Cordier explained the principles of this method in his memoir to the "Académie des Sciences" in 1855, reprinted afterwards with the *Description des Roches*, published in 1868, from the manuscript of the illustrious lithologist, Ch. d'Orbigny.

It is necessary to first reduce to powder, by pressure as much as possible, rather than by trituration; then separate the elements of different densities, by means of repeated washings, upon a glass plate more or less inclined; finally, examine by the microscope the isolated particles, comparing them with the ordinary elements of rocks brought to the same degree of fineness, subjecting them also to the action of acids, blow-pipe magnet, etc.

M. Ad. Brongniart has examined directly with the micro-

scope, the thin laminæ cut from petrified wood. The success with which this eminent botanist has conducted his examinations of fossil wood, is well known. For some years this simple process has been applied to the study of rocks proper. By the aid of considerable magnifying power, laminæ of rocks, if thin enough to be transparent, may be successfully examined; a scale, obtained by a blow, may be cemented by Canada balsam to a plate of glass. Such examination serves often to make known, either by their form or their color, the microscopic elements of basaltic or adelogenic rocks. It permits, also, the study of the minutest details of the mineral structure of rocks. It is often difficult to distinguish, under the microscope, the separate elementary constituents, even when the fragment is thin enough to be transparent. Polarized light is often successfully employed in such a case. Two Nicol prisms are adapted to the microscope. One is placed below the stage; this is the polarizer. The other is placed above the eye-piece, between the microscope and the eye; this is the analyzer. When the Nicol prisms are so placed that their sections are at right angles, the light is cut off and the field is dark.

I. 1. Now if we place upon the stage a crystal of the cubic system, it does not in general modify the effect produced by the Nicols.

The ordinary elements of rocks belonging to this system, and susceptible of certain degrees of transparency, are: Fluor-Spar, Rock-salt, the Alums, Analcime, the Garnets, Blende, Sodalite, Amphigene.

Analcime and Amphigene (Leucite) present an exception and re-establish the light in the dark field in virtue of a curious property which Biot has called *polarization lamellaire*.

The crystals of the five remaining crystalline systems dissipate all the obscurity produced by the crossing of the principal sections of the Nicols. They fail, however, to do this under the following circumstances:

2. Substances crystallizing in the hexagonal system (*Emer-*

ald, Apatite, Tourmaline, Quartz, Nepheline, Chlorite, Pennine, Calc-Spar, Dolomite, Siderite); those of the quadratic system *(Zircon, Idocrase, Wernerite, Apophyllite)* do not divide the ray which traverses them perpendicular to their bases; so the plates of these minerals, having faces normal to the rays, remain obscure between two Nicols when they are traversed by a parallel beam; this condition is nearly fulfilled when they are viewed under the microscope; it should be added, however, that if they are observed directly with the eye, the minerals being placed between an analyzer and a polarizer, they receive convergent light and will exhibit, in such cases, around their optical axes, circular rings of brilliant colors, traversed by a dark cross, whose branches are parallel to the two sections of the Nicol. For explanation of this phenomenon, we refer the reader to treatises on physics or mineralogy.

If minerals of the hexagonal or quadratic systems are cut in plates with faces parallel to each other and to the optical axes, and, consequently, parallel to their bases, they leave the field dark when the optical axis is parallel to the principal section of one of the Nicols.

3. Place upon the stage a mineral of the orthorhombic system—right prism with a rectangular base—*(Sulphur, Topaz, Staurotide, Andalusite, Mica, Mesotype, Stilbite, Peridot, Arragonite, Cerusite, Barytes, Celestine, Anhydrite)*; we find three directions, each at right angles to the other two, under which the mineral permits the dark field of the microscope to remain dark. These three directions are parallel respectively to the edges of the triangular prism; that is to say, to the height, length and breadth, or, as the base may be a rhombus, to the two diagonals of this base. If the object is slightly displaced, so that one of these edges is no longer parallel to the principal section of the Nicol prism, the dark field is illuminated.

Enstatite, for example, cleaves in fibrous laminæ, the fibres being parallel to the intersection of the planes which are regarded as the lateral faces of the rectangular prism. When a

lamina is obtained by cleavage from this mineral, the obscurity remains only when the general direction of the somewhat discontinuous fibres is parallel to one of the Nicol prisms.

4. Crystals of Augite or Diallage produce this effect only in directions generally oblique to their edges. If there is interposed, between the polarizer and analyzer, a lamina of any substance whose form is derived from a rectangular or rhombic prism inclined in one direction, but in one only, the obscurity remains for three directions, of which one only is parallel to one of the edges of the rectangular prism. This unique direction, parallel to the base, is perpendicular to the line of greatest inclination. The two others are found to bear different degrees of obliquity to the crystallographic lines. The minerals of this system, widely diffused among the rocks, are: *Epidote, Orthoclase, Wollastonite, Pyroxene, Amphibole, Gypsum.* When we know the direction of a given face of the mineral by the fracture in one of these substances, and the position of the regular lines which limit the contour, it is sometimes useful to measure the angle of the direction which allows the obscurity to remain when it is parallel to one of the Nicols and one of the known crystallographic lines; this angle may serve to determine the mineral under examination. In order to measure this angle, a divided circle is adapted to the microscope, upon which turns an index carried by a double refracting prism, which is substituted for the Nicol analyzer.

5. Finally, if the forms of a mineral substance can be derived only from the last crystallographic system, the directions for which the obscurity persists, are without any assignable relation to the crystallographic lines.

II. But the service rendered by polarized light does not end here. Laminæ, even if colorless, acquire, when placed between two Nicols, colors which vary with their thickness and with the material. Also confused mixtures with materials of uniform thickness but of different nature, shine under these conditions, with different colors which serve to distinguish them one from

the other. Small irregular grains of quartz are easily recognized by this means, either in sandstone, where it is almost the only mineral, or in granite or porphyry where it is associated with Feldspar.

Moreover, the color exhibited by a crystal belonging to any other than the cubic system, varies with the surface which is presented to the light. This explains why, in basalts, the crystals of Feldspar, distributed parallel to their planes of lateral cleavage, present, when observed between two Nicol prisms, alternate bands of different colors.

III. Another fact of which it is necessary to take cognizance in microscopic analyses, is the dichroism of minerals. Often a crystal affords colors which change with the direction in which it is regarded by transmitted light. We can, with a fragment of Calc-spar obtained by cleavage, observe two colors, or, at least two different shades, in nearly all colored crystals except those of the cubic system. M. Tschermak has been able to distinguish Augite from Hornblende by means of these colors.

IV. I shall recommend, finally, for this kind of research, a process which has often served me with advantage, and which consists in the employment of a lamina of Selenite of sensible thickness, but still of such thinness as to afford colors between two Nicols. Superposed upon a thin section of any substance which affords a color between the Nicol prisms under the microscope, this Selenite heightens the brilliancy of the colors.

PART FIRST.

PROPERTIES OF THE PRINCIPAL MINERALS WHICH COMPOSE THE ROCKS.

(A description of the leading minerals which constitute rocks, is alone afforded in this first part.)

FELDSPARS.

(Silicates of Alumina, with either soda, potash or lime).

Hardness 6, being scratched by Quartz; generally cleavable in two directions having an angle between them of from 86° to 90°; all more or less easily fusible.

Five different Feldspars with well-determined characteristics, are known: *Orthoclase,* in which potassa predominates; *Albite,* in which soda predominates; *Anorthite,* having a base of calcium or lime; and two or three other Feldspars of more complex composition; *Oligoclase,* having a base of soda and lime; and *Labradorite,* having a base of lime with a smaller proportion of soda.

Orthoclase (Aluminum potassium silicates).—Form: an oblique prism with a rhombic base, modified generally upon the lateral faces. $mm = 118° \ 48'$; $pm = 112° \ 16'$; $ph^1 = 116° \ 7'$; $pg^1 = 90°$.

Direction of cleavage: at first, parallel to p, then to g^1.

Dominant forms: elongated in the direction of the heights (Fig. 1); elongated, also, in the direction of their bases (Fig. 2).

The crystals exhibit many different modes of grouping, the principal of which are the following: (1) coupled in

Fig. 1.

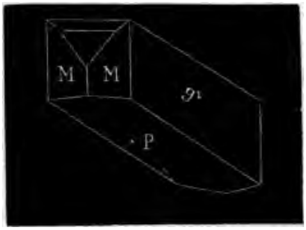

Fig. 2.

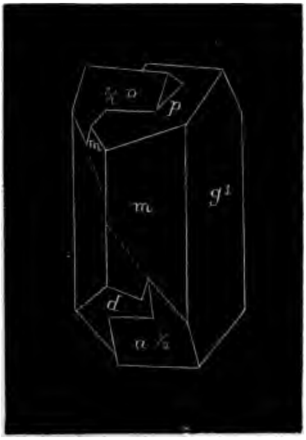

Fig. 3.

inverted manner upon a facet which modifies the lateral angles of their bases (and inclined 45° 3′ to the vertical axis), so that the two bases P become adjacent to each other, also the lateral faces g^1; (2) two crystals joined in a reverse manner, like an object and its reflection in a mirror, having their vertical edges parallel and partly interpenetrating each other, having one part common and the other part free (Fig. 3). The two bases form a re-entrant angle of 127° 46′; (crystals of granite and porphyries are examples).

If a fragment of one of these rocks be made to reflect a beam of light, in order to distinguish the basic cleavage of one of its feldspar crystals, the light from one portion of the base only is obtained; the reflection from the cleavage of the other portion is obtained only by turning the rock through an angle supplementary to the preceding. In granites and pegmatites, the small crystals are simple and exhibit the faces p and g^1, and a face h^1 with very unequal fractures.

Colors: white, reddish-white, gray, green, bluish-green. Powder: grayish-white. Lustre: vitreous; sometimes pearly upon the cleavage faces; all degrees of transparency. Hardness 6. Specific gravity 2.5 to 2.6. Not acted upon by acids, except hydrofluoric and ammonium fluoride. It contains from 64 to 67% of Silica.

Varieties: *Adularia*, colorless and nearly transparent; *Ama-*

zon-stone, green or greenish-blue, colored by copper: *Loxoclase*, containing more Soda than Potash; *Mikroklin*, containing about equal proportions of Soda and Potash; *Sanadin*, being the form found in Pumice and Trachyte.

Modifications of structure: laminated; granular (Leptynite); compact (Petrosilex); vitreous (Obsidian and Perlite).

The general characteristics exhibited by Orthoclase in rocks are its vitreous or slightly pearly lustre, its laminated fracture, its hardness and its fusibility before the blow-pipe. In order to observe this latter characteristic, it is necessary to break it into as small fragments as possible; then choose from among them those which have the sharpest edges or points, and place one in the platinum pincers; apply the hot flame of the blow-pipe to the thin edge of the fragment; after a few seconds, the edges may be seen, by the aid of a lens, to be slightly rounded.

Albite (Aluminum-sodium, silicate).—Form: a doubly oblique prism, often modified. The two cleavages, generally the most marked, have, between them an angle of 86° 24′ and corresponding—the first, pearly, to the base p; the second, more vitreous, to the face g^1 (Fig. 4). The crystals are generally reversed, the one upon the other, giving rise to the form exhibited in the figure. Hardness, somewhat greater than Orthoclase. Specific gravity 2.6; sometimes as high as 2. 63. The color varies from milk-white to green or even to red. It is generally white in the rocks. In order to analyze it, it is necessary to treat it with barium hydrate or ammonium fluoride. It contains about 68% of Silica.

Fig. 4.

Oligoclase (Aluminum-sodium-calcium silicates). — The principal cleavage-plane has a vitreous lustre and is marked by parallel striæ. A cleavage-plane of the second order, makes with one of the first order, an angle of 86° 10′; the fracture in other places is somewhat splintery. The striæ of the base arise

from a grouping analogous to that which we have described in Albite, but which is much more fully represented in this mineral. The color is a dull or greasy white, grayish-white, greenish, yellowish, or reddish. Hardness, about 6; specific gravity, about 2. 7 (just enough higher than Albite to admit of identification). Before the blow-pipe, Oligoclase fuses more easily than Albite to a colorless glass, coloring the flame yellow. It is readily attacked by acids. Oligoclase contains about 80% of Silica.

Andesine (Oligoclase, very rich in Lime).—Oligoclase is generally accompanied, in the rocks, by silicates of magnesia and iron more or less aluminous: Micas, Chlorites, Amphiboles, Pyroxenes. It represents, in a manner, the average of the other Feldspars, and is found associated with all; with Orthoclase in the syenites; with Albite in the diorites; with Labradorite in the melaphyres. Sometimes it forms in syenite the nucleus of a crystal of which Orthoclase furnishes the envelope. In the granites of Finland it surrounds the Orthoclase. Oftentimes the crystal is enveloped in a yellow crust produced by the carbonic acid of the air.

Labradorite (Aluminum - calcium - sodium, Silicates).— Form: doubly oblique prism. Crystals are rare. The face of the principal cleavage exhibits a vitreous lustre and makes, with the secondary cleavage-plane, an angle of 86° 40′. The facet is marked by striæ, occasioned by grouping as in Oligoclase; but to this grouping is added another, intersecting it as in Orthoclase. The color varies from gray and grayish-white to greenish-gray. Labradorite often exhibits a beautiful play of colors of various hues, from the faces g^1. Hardness 6. Specific gravity 2.68 to 2.74. Before the blow-pipe, Labradorite fuses more easily than the preceding species to a white enamel. It colors the flame yellow, and is imperfectly dissolved by hydrochloric acid even when in powder. Concentrated sulphuric acid dissolves it with a separation of Silica.

Saussurite is found with Diallage in Gabbros; very tenacious and very heavy; greenish-gray or greenish-white, rather

dull. Hardness 5.5 to 6.5. Specific gravity 2.79 to 3. Labradorite gives rise to a calcareous clay or marl, and a soluble calcium carbonate.

Anorthite (Aluminum-calcium Silicate).— Form: a doubly oblique prism. Hardness 6. Specific gravity 2.75. Two very decided cleavages making an angle with each other of 85° 48′. Crystals: colorless and transparent, very clear, or white and translucent; exhibit a pearly lustre upon the cleavage faces. Easily fusible before the blow-pipe and completely decomposed by hydrochloric acid, with separation of Silica.

MINERALS ALLIED TO THE FELDSPARS.

1. **Nepheline** (Aluminum-sodium-potassium-calcium, Silicates).—Hexagonal prism, sometimes modified upon its edges and upon all edges alike (Fig. 5). Cleavage: hexagonal, imperfect. Crystals partially or quite transparent. Hardness 6. Specific gravity 2.6. Before the blow-pipe fuses rather easily to a glass; is soluble in acids with a gelatinous deposit of Silica.

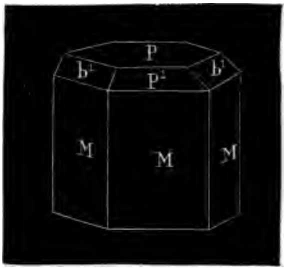

Fig. 5.

Elæolite.—Possesses external characters slightly different from those of Nepheline. Has a greasy lustre in the fracture, tending to pearly on the exterior. Color varies from brown, to green or red.

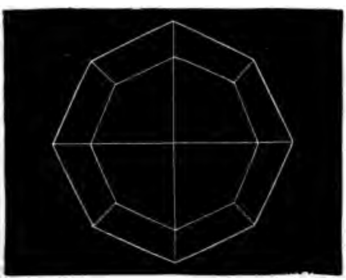
Fig. 6.

2. **Amphigene** or **Leucite** (Aluminic-potassic Silicate). Form: trapezohedron of the cubic system (Fig. 6). Possesses a conchoidal vitreous fracture. Numerous but imperfect cleavages. Rarely colorless and limpid; more often whitish and often altered to a sort of Kaolin with a reddish tint.

3. **Sodalite** (Aluminum-sodium Silicate).—Crystals with a vitreous lustre; colorless, or from grassy green to azure blue, losing this color by heat; fusible to a colorless glass; dissolving to a gelatinous mass in acids. Hardness 5.5. Specific gravity 2.29. Form: dodecahedron, generally elongated in the direction of one of the octahedral axes. Cleavages parallel to the faces of the dodecahedron.

4. **Hauyne** (Composition same as preceding with Sodium and Calcium Sulphates).—Crystals generally blue, belonging to the cubic system. Cleavable along the faces of a dodecahedron. Fusible with difficulty before the blow-pipe.

MICAS.

(Silicates of Alumina and Potash with or without Magnesia.)

Many Micas also contain Fluorine, Lithium, Sodium, and in some, very small quantities of Cæsium or Rubidium. The

Fig. 7.

primitive crystalline form is a right prism with a rhombic base (Fig. 7). The figure is nearly always modified upon its lateral edges and has the appearance of a regular hexagonal prism. The cleavage is quite perfect, parallel with the base, and so easily affected that all sands and rocks which have resulted from the disaggregation of crystalline rocks, of which Mica is an essential element, exhibit the thin hexagonal laminæ of this mineral.

The laminæ are flexible and elastic; the lustre is bright, perhaps a little oily, and sometimes pearly. When examined by the microscope, the laminæ readily exhibit the colored rings

which belong to crystals of two optical axes. The angle of the axes varies from 0° to 4° in the *Biotites*, from 5° to 20° in the *Phlogophites*, 45° to 75° in the *Muscovites*.

Muscovite Micas, very rich in magnesia, fuse to a white enamel; they are not easily attacked by hydrochloric acid. These are the Micas of brightest lustre. They are of various colors, silver-white, yellowish, golden-yellow, brown, red, green, rose, black. They occur as an essential element in Granite, Gneiss, and Mica Schist. With this group should be ranked *Lepidolite*, which contains Lithium and oxide of Rubidium, and which colors the flame, at the moment of fusion, a purplish red. After fusion it is attacked by hydrochloric acid with a gelatinous deposit of Silica.

Biotites (Micas rich in magnesia). — Of a black or deep brown color, attacked by concentrated sulphuric acid, leaving a residue of pearly scales of Silica.

One variety of this class is *Rubellan*, of a rose-red, opaque or black. The Magnesian Micas alter more readily than the Potash Micas, and exfoliate in innumerable scales.

A certain number of minerals resemble the Micas in possessing an easy cleavage nearly in one plane; a bright lustre, often pearly upon the cleavage-face; and presenting hexagonal laminæ which contain water, easily recognized by heating in the open tube.

Damourite (Aluminum Silicate and Potassium Hydrate).— In whitish or yellowish scales with a pearly lustre; before the blow-pipe it swells up and fuses with difficulty to a white enamel. It is entirely decomposed by concentrated sulphuric acid. Specific gravity 2.79.

Paragonite (Aluminum Silicate and Sodium Hydrate).— In schistose masses formed of fine scales which are yellowish, grayish-white, greenish; lustre rather dull, though pearly and translucent. Infusible before the blow-pipe. Specific gravity 2.89.

Sericite. — Mica in silky scales, forming the undulating

laminæ of some of the schists. Hardness 1. Specific gravity 2.897. Silicate of Aluminum and Potassium, and much resembles Damourite.

CHLORITES.

(Talcose Micas). Substances intermediate between Mica and Talc. Those which enter into the composition of rocks, forming, often, foliated masses. Their crystals are nearly always laminated, the scales being hexagonal, having a perfect cleavage as easy and brilliant as Mica and Talc; divisible into fine scales, flexible, slightly elastic; leek-green or olive-green color, more or less blackish, somewhat rarely, bluish; greasy, brittle; the powder unctuous to the touch. Density, about 2.8. Yields water in the closed tube. Decomposed by concentrated sulphuric acid, also in boiling hydrochloric. Before the blow-pipe it is more or less easily fused to a black enamel, which is magnetic for the reason that it contains more or less iron. Composition of Chlorite: Silica 26.88, Magnesia 13.84, Alumina 17.52, Oxide of Iron 29.76, Water 11.33.

The Chlorites comprise also the *Ripidolites* and *Delessites*. The others (*Clinochlores*), much less rich in oxide of iron, having a density always less than 2.8. They are less easily fusible before the blow-pipe where several of their varieties exfoliate; their color is green, resembling that of the emerald. Their optical characters are of the oblique system, with a rhombic base, but their exterior properties are not distinguished from the preceding. They are decomposed by the aid of concentrated hydrochloric acid after a prolonged boiling; more easily by sulphuric acid.

Finally we have the *Pennines*, having optical form and properties of the rhombohedral system; they have also a basic cleavage, greasy lustre and the general properties of the Chlorites.

Ottrelite (Hydrated Silicate of Alumina, Iron and Magnesia).—Crystallizes in hexagonal tabular plates; cleavage parallel to the base; blackish-gray color; lustre a little greasy,

somewhat translucent; density greater than 4, harder than the point of a graver's tool; fusible with difficulty to a black, magnetic enamel; decomposed by boiling sulphuric acid.

Pyrophyllite (Silicate and Hydrate of Alumina).—Contains sometimes a little Magnesia or Iron oxides; is found in right prisms with a rhombic base, cleavable and elongated parallel to the base; assumes, before the blow-pipe, considerable volume, spreading out like a fan without completely fusing; yields water in a closed tube, and is but slightly attacked by sulphuric acid. It has a greasy lustre, a white or greenish-white color; soft; yields an unctuous powder; exhibits the flexibility and want of elasticity which distinguishes Talc.

The *Pagolite* of China, and the *Parophite* of Canada, are substances equally talcose in their nature—being Silicates of Alumina with more or less Magnesia.

TALC AND STEATITE.

(Hydrated Silicate of Magnesia). Silica about 62%; Magnesia, 32% to 33%; water 48%.

1. **Crystallized Talc.** — Hexagonal laminae derived from a right prism with a rhombic base, with angles — as in the Micas — 60° and 120°; greasy to the touch; non-elastic; greenish-white, silver-white, or a leek-green color. The base is cleavable and has a pearly lustre. Powder or streak is white; hardness 1.

2. **Massive Talc Steatite.**— In granulated masses; in aggregated laminæ fibers; radiated; schistose. Before the blow-pipe, the laminated Talcs exfoliate more or less; they fuse with difficulty upon the edges to a white enamel; yield a little water in the closed tube; not attacked by acids.

AMPHIBOLES.

All the species of this group crystallize in oblique prisms which cleave parallel to their faces *(mm)* under an angle of 124° 11′ to 124° 30′. Generally the crystal is modified on its lateral

edges, and terminated by the base, which latter is modified upon its posterior edges in such manner that its form resembles a hexagonal prism, bearing a rhombohedral summit, similar to that of Tourmaline; but the measure of the angle of the three terminal facets serves to distinguish the form of the crystal.

Tremolite (Magnesium and Calcium Silicate).—Hardness, 5 to 6. Specific gravity, 2.9 to 3. Colorless, white, apple-green, or gray; often fibrous with a silky lustre. It fuses easily with a slight ebullition to a white semi-transparent glass, not attacked by acids. The Jade of China has a greasy lustre; exhibits a scaly fracture; is of a whitish color, more or less greenish; and is a compact variety of Tremolite.

Actinolite (Iron, Magnesium and Calcium Silicates).—Isomorphous with the preceding. Density, 3 to 3.2. It is found in greenish masses, radiated in Mica schists.

Hornblende.—Composition, analogous to the preceding, but containing Alumina. Black when in large masses, but deep green or brown when in thin laminæ. One variety, *Pargasite*, is of an olive-green or greenish-black, and sometimes of a deep blue. The powder of Hornblende is a greenish or brownish gray. Hornblende presents itself quite frequently, in rocks, in fibrous crystals which have the appearance of wood-charcoal, but in which may be perceived the two cleavage-planes which have an inclination of 124°, and present a brilliant vitreous lustre when turned successively toward the light. In those rocks in which it appears as an essential element, Syenites, Diorites, Andesites, etc., its powder is greenish-gray. In Basalts, where it appears as an accidental element, the powder is generally brownish. Hornblende fuses to a black enamel, and is attacked by acids when it contains much iron.

PYROXENES.

(Bi-Silicate of Magnesia, or its isomorphs).

Diopside (Calcium and Magnesium Silicates).—Colorless, white, pale green, olive-green, grayish-green.

Hedenbergite (Calcium and Iron Silicates).—Fuses to a black mass more or less Magnetic.

Augite (Calcium, Magnesium, Iron, Aluminum, Silicate).—This species contains about 8% of Aluminum. Either black, greenish-black, or brownish-black. The powder is gray; sometimes slightly yellowish, or greenish; it fuses with more difficulty than Hornblende to a black mass, more or less scoriaceous. Fracture, conchoidal. Density, about 3. Hardness, a little less than 6. Contains about 50% of Silicate.

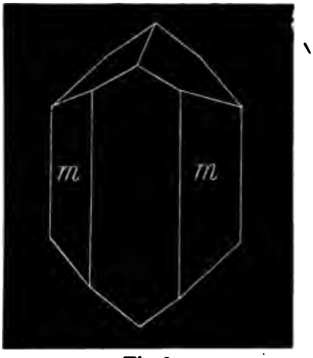

Fig. 8.

Form: monoclinic prism; (*mm* = 87° 5′); cleavage difficult, following the faces *m*. Figs. 8 and 9 show the ordinary forms of Augite.

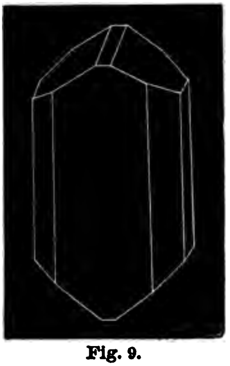
Fig. 9.

Fig. 10 shows the ordinary form of Hornblende. It also shows by the ellipses drawn on the faces of the crystal, the position of the axes of thermic conductibility of Hornblende. If a little melted tallow be smeared upon the faces of these crystals, it will, in cooling, exhibit the figures represented in the diagrams. The elliptical figure on the face g^1, in the Amphiboles, has its longer axis inclined only 4° or 5° to the vertical edge. Upon the base, the longer axis is directed to the right and left, while in the Pyroxenes the longer axis is at right angles to this direction.

Augite and *Hornblende* are easy to distinguish, when they are crystallized. In the granular varieties, Hornblende is always laminated, slightly fibrous, and the two cleavages, with their angle of 124°, may be perceived. The grains of

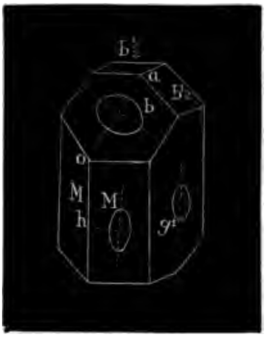

Fig. 10.

Pyroxene have, in general, a vitreous conchoidal fracture, a lustre slightly greasy, and rarely showing the cleavages which make between them an angle of 90°.

In the fine-grained varieties, the distinction is more difficult. Hornblende is more fusible than Augite. Its powder is deeper in color, greenish or brownish. When these two minerals are found intimately mixed with others—Feldspar, for example—and forming paste in Porphyry, they may be recognized in some cases by means of a magnifying glass. In laminæ thin enough to be transparent, the microscope enables one to recognize the angle $b\frac{1}{2}$ $b\frac{1}{2}$ of Augite, or the fibrous laminæ of Hornblende. If such laminæ be seen through a crystal of Iceland spar, Amphibole exhibits two images whose colors vary from yellow to brown, or green, or violet, according to the faces which are presented to the plate. Augite, under the same conditions, exhibits greens and yellows, and their combinations.

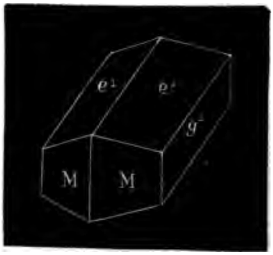

Fig. 11.

Smaragdite.—An assemblage of crystalline laminæ of Amphibole and Pyroxene, alternately placed; of beautiful green color, and more or less clear.

Olivine, or **Peridot** (Iron and Magnesium Silicates).—A right prism with a rhombic base. Hardness, 7; density, 3.4; conchoidal fracture; color, greenish-yellow to olive-green. The variety so abundant in certain basalts is granular, and of a more or less deep green color; often in the very ferruginous varieties, the colors are a dirty red or brown. Olivine is infusible before the blow-pipe; reduced to a fine powder, it forms a gelatinous mass with acids.

Enstatite (Magnesium Silicate with a little Iron).—Cleavage parallel to the faces of a right prism with a rhombic base, whose angle is about 93°. Only fusible with great difficulty before the blow-pipe; has a density of 3.9; pearly lustre, somewhat fibrous aspect; of a grayish, yellowish or greenish-white color; the powder is quite gray. Not attacked by hydrochloric acid.

Bronzite.—Differs from the above only by qualitative composition, containing a certain amount of iron; it has a brighter lustre and is almost metallic upon the cleavage-face. It is of a bright yellow, brown or olive-green. Not attacked by acids.

Hypersthene.—Contains as much iron as magnesia. It is distinguished by a lively red-brown color with a coppery lustre on the cleavage-face; it fuses to an opaque greenish-gray glass.

Diaclasite.—Bronzite slightly hydrated, yellowish or greenish-gray; hardness, 3. 5; fuses easily to a brownish-green enamel; not acted upon by acids.

Diallage (Calcium and Magnesium Silicate).—A variety of Pyroxene diopside. It differs from the related minerals by its unique and perfect cleavage parallel to the face h^1, of which the lustre is bright, sometimes pearly, often metallic, bearing some resemblance to the Micas. Diallage is yellow, yellowish or greenish-gray, or brown; is feebly translucent at the edges. Hardness, about 4. Density, 3.75. Is not attacked by acids. Is fusible with difficulty before the blow-pipe.

Cordierite or Dichroite (Aluminum, Calcium, and Magnesium Silicates).—It crystallizes in six-sided prisms, derived from the right prism with a rhombic base. Hardness 7.5. Density 2.6. Fusible with difficulty upon the edges; not easily attacked by acids; has a vitreous fracture; when seen by transmitted light, it is azure blue in one direction, and grayish or yellowish in the other.

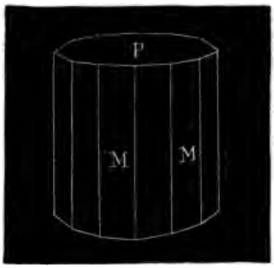

Fig. 12.

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Pinite resembles Cordierite in form and composition, but possesses a hardness of only 2.5, with a density of 2.8. It has, generally, a greasy lustre and an amorphous structure.

MINERAL SPECIES WHICH APPEAR OCCASIONALLY AS ESSENTIAL ELEMENTS OF ROCKS.

Topaz (Aluminum, Silicate and Fluoride).—It has a brilliant vitreous lustre; of yellow or reddish-yellow color, generally; sometimes of a rose color. The Topaz of Siberia is bluish or greenish-white; hardness, 8; density, 3.5; has a basic cleavage and is infusible before the blow-pipe. Its crystal is an orthorhombic prism; *mm*=124° 17′.

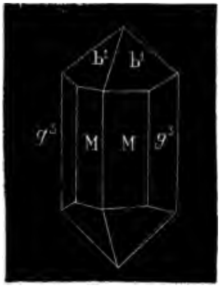

Fig. 13.

Tourmaline (Aluminum, Sodium, Magnesium, Boro-Silicate).—Some species contain much iron, and are distributed through the rocks. It crystallizes in prisms of from 9 to 12 faces, terminated by rhombohedral summits. The crystals are generally black, but the powder of the crushed mineral is brown. Hardness slightly greater than that of Quartz. Density 3.2. Fuses to a black scoria.

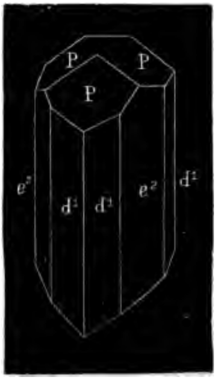

Fig. 14.

Epidote (Calcium and Aluminum Silicate, containing more or less Iron).—Form: oblique prism with a rhombic base; ph^1=115° 27′. Cleavage perfect, parallel to *p*. Color; green, sometimes yellow, red, or brown. Hardness 6.5. Density 3.3 to 3.45. Before the blow-pipe, Epidote fuses with intumescence to a black mass, which is generally magnetic. Reduces to a jelly in acids, only after calcination. It occurs in various forms;

acicular, fibrous, granular, compact. In rocks, it is the pistachio-green color that predominates.

Fig. 15.

Garnet.—This group contains a great number of species; the dominant forms are, rhomboidal dodecahedrons, trapezohedrons (Fig. 16) and a combination of the two. Hardness, about the same as Quartz. The Lime Alumina garnet, called *grossulaire,* has a vitreous lustre; a greenish, sometimes white color; easily fusible to a greenish or grayish glass; easily attacked by hydrochloric acid; forming a jelly after fusion. *Pyrope,* the Magnesia Alumina garnet, sometimes contains chromium; is of a blood-red color; fusible before the blowpipe; not attacked by acids. *Almandite,* the Iron Alumina garnet, is of a red, or brownish-red color; varying from transparent to translucent and opaque; fusible to a globule, often magnetic. Density from 3.8 to 4.2. Forms a jelly in hydrochloric acid after fusion. Lime-Iron garnet, *Melanite;* black; fuses to a bottle-green globule. A variety of this, called *Topazolite,* is of a clear yellow color. Still another variety of yellowish-green color called *Aplome* or *Jelletite,* is fusible to a black glass very magnetic.

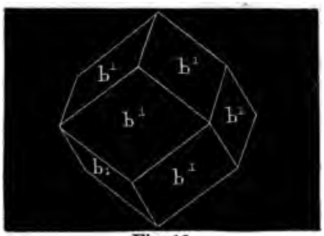

Fig. 16.

Staurotide (Aluminum and Iron Silicate).—Crystallizes in right prisms with a rhombic base, and generally in pairs, crossing each other (Fig. 18). Deep brown-

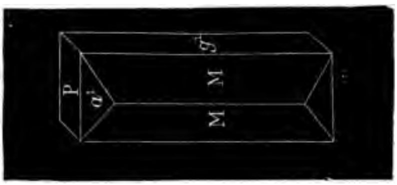

Fig. 17.

ish-red color; infusible before the blow-pipe; insoluble. Density 3.7; Hardness 7.5.

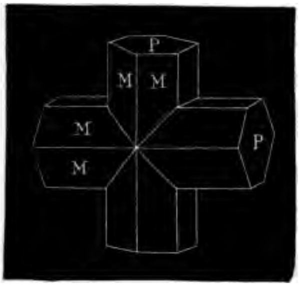

Fig. 18.

Andalusite. (Aluminum Silicate).—Form: right prism with a rhombic base, with an angle of about 91°. Infusible; insoluble. Density 3.14. It will scratch Quartz when the crystal is pure, but is generally earthy in structure and more or less friable. The crystals often envelope fragments of the rock in which they are found. These fragments are often regularly arranged as in Figs. 19 and 20.

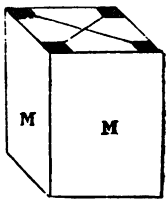

Fig. 19.

Sphene (Calcium Silico-Titanate). Form: monoclinic prisms generally grouped. The group generally has a triangular section and bears some resemblance to a little boat. Soluble in concentrated sulphuric acid, when reduced to powder; fuses with intumescence before the blow-pipe. Hardness 5.5. Density about 3.5.

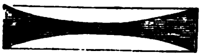
Fig. 20.

PART SECOND.

CHAPTER I.

FELDSPATHIC ROCKS.

1. **Granite:** An aggregation or assemblage of crystals of Feldspar, Quartz, and Mica. The principal species of Feldspar is Orthoclase. Color: white, grayish-white, yellowish, reddish, rose, flesh color or deep red; rarely green. It is distinguished by its even and brilliant fracture, its pearly lustre, and by its outline, which is seldom regular, but in which may be recognized rectangles and parallelograms. Quartz is always found in irregular, angular grains; color: white, smoky, gray, very rarely bluish or red; has an irregular fracture and a vitreous and greasy lustre. Under the microscope, it appears to be full of minute cavities, which contain, according to Sorby, water holding in solution chlorates or alkaline sulphates. Mica is made up of laminæ, often hexagonal, brilliant, white or black, rarely of a yellow, gold, or green color; always easily detached by means of a penknife, in little elastic scales. The potassic Micas appear more frequently than the magnesium Micas.

Orthoclase is often accompanied by Oligoclase of a grayish-white or greenish-white color, less transparent, richer in soda, having a more or less greasy lustre.

The name of *Granitite* is proposed for the granite of Riesengebirge, which is characterized by the abundance of Oligoclase and the scarcity of Quartz. The granite of the Isle of Elba offers analogous characters: Orthoclase of a flesh color; white Oligoclase, with a brilliant lustre upon the face made by the fracture; Mica in black laminæ; little Quartz. It is much

the same with the granites of Brittany and Normandy. This distinction has not been generally admitted.

M. Delesse has obtained the following proportions for the red granite of Egypt: red Orthoclase, 43; white Oligoclase, 9; Quartz, 44; black Mica, 4.

M. Durocher *(Recherches sur la crystallization des roches granitiques,)* has given the relative quantity of the elements of several granites :—

Granite of Becanne: Feldspar, 45%; Quartz, 35%; Mica, 20%. Granite of Hédé, same class: Feldspar, 20; Quartz, 20; Mica, 60. The density of granite is from 2.6 to 2.7. The oxygen of the Silica being taken at unity, that of the bases is about 2.6.

Accessory elements: *Talc (protogenic granite); Chlorite (chloritic granite); Hornblende (syenite granite); Tourmaline (tourmaline granite); Ferruginous Granite*, in scales; *Cordierite (cordierite granite); Pinite*, in prisms with numerous lateral faces, of a yellowish-gray, or green color; *Albite*, of a milk-white color; *Epidote (epidote granite)*, in small acicular crystals of a yellow or green color; *Graphite*, in laminæ, very soft and brittle, which replace a more or less great part of Mica; also the following gems: *Emerald, Topaz, Zircon, Garnet*, etc.

Varieties: Homogeneous granite, in the mass, whose mineral constituents preserve the same dimensions throughout. Porphyritic Granite, in which certain crystals of Feldspathic Orthoclase are more developed than others, and often of another tint, or of a different lustre, thus giving the aspect of porphyry. Regarding the size of the constituents of granite we can distinguish as coarse granites those in which the crystals attain the size of the fist; and those as fine-grained in which the crystals are only the size of a millet seed.

The name of Beresite is given to a granite which is poor in Mica and is altered. M. Pisani has given that of *Luxuliane* to a porphyritic granite of Luxulion, in which the Tourmaline, in prisms of a deep green color, is associated with red Orthoclase

which takes the place of Mica. The minerals which are found in granite are not very abundant, but the species are very numerous. The following may be cited, Andalousite, Allanite and Gadolinite; Oxide of Tin, Epidote, Fluorite, Garnets, Native Gold, Orthide, Pyrites, Tourmalines, Uranite and Chalcolite; Wernerite, Zircon, etc.

Granites constitute the largest system of massive rocks that traverse the crystalline Schists, and often the transition systems. Enclosed at their base in these systems, they extend above the over-lying systems in vast peaks and ridges; they also form dikes or veins such as are found in the Melaphyre. They present also the characteristic trait of throwing out very complex ramifications which anastomose, so to speak, among themselves within the mass of the encasing rock. They are more rarely found in the upper primary rocks, and have only a slight importance in the secondaries.

2. **Breccia granite.** Fragments of granite ordinarily angular, often very large; united by a natural cement also granitic, but different from granite in grain and the proportion of the essential minerals, above all of Mica.

3. **Conglomerate granite.** Fragments of granite, generally rounded in form, often very large, united by a cement of an argillaceous nature.

4. **Granitic Sand.** Sand formed of the elements of disintegrated granite.

5. **Protogine** (Protogine gneiss, Protogine granite). Talcose granite. This is a granite in which, more or less, Mica is replaced by a Talcose mineral and Clinochlore.

Essential Elements: Feldspar, Quartz, Talc or Chlorite. In the Protogine of Mont Blanc, the Feldspathic Oligoclase is white or grayish-white, dull and laminated; often in large crystals with very regular contours. The Quartz is presented in grains of a smoky or violet-gray color; the Talc, in small laminæ more or less irregular, of an emerald-green, or sea-green, or gray color; very brittle and unctuous to the touch, especially

when reduced to powder. Mica rich in iron, which is perhaps a Clinochlore, forms greenish laminæ, sometimes slightly greasy to the touch. Oligoclase is the most abundant Feldspar. According to M. Delesse, Silica forms about 75% of the rock. The more abundant is the Quartz; the more granular is the rock. An excess of Talc makes the rock schistose. The proportion of the Oxygen of the bases to that of the Silica is 0.25. M. Durocher estimates, in the Protogine of Savoy, the Feldspathic proportions at 50%; Quartz 35%; the remainder being Chlorite and Talc. In a Protogine of the Eastern Pyrenees, Feldspar is estimated at 45%; Quartz 30; Chlorite and Talc at 25%. Protogines often become schistose and pass into Chlorite schists.

In the Protogines of Tarascon, Durocher found 65% of Feldspar; 30 to 35 of Chlorite; and very little Quartz.

6. **Pegmatite.** Assemblage of Feldspathic Orthoclase, laminated, white, yellow, green, red, etc., showing rectangular cleavage-planes often clearly crystallized. The Quartz is also crystallized in elongated prisms with six sides, terminating in pyramids with six faces, more or less regularly developed; and sometimes, but more rarely, double pyramids with six faces.

The Quartz in crystallizing, seems to have been forced to fill the place left by the Feldspar. The individual crystals of Pegmatite are sometimes of enormous volume. In other varieties they are reduced to the ordinary dimensions of granite. This rock is nearly 78% Silica. In the variety of Pegmatite known as *graphic*, the crystals of Orthoclase are crossed by those of Quartz. The latter are elongated, parallel, and distributed in the Feldspathic mass, in such a manner as to resemble hieroglyphic characters.

Accidental elements: *Tourmaline, Topaz, Albite, Beryl, Garnet, Gadolinite, Orthite, Apatite, Columbite, etc.*

Pegmatite forms veins in gneiss, granite, and leptynite. The Feldspar is often altered; it is then the most valuable kind of Kaolin. (Saint-Yrieix, near Limoges.)

7. **Leptynite.** *Weisstein, Granulite.* A granular mass; sub-crystalline; often compact; formed of white, grayish, yellowish, or reddish Orthoclase. The facets of this rock are analogous with those of sandstone, but it fuses to a white enamel. Often it becomes schistoide and exhibits cavities with garnets or grains of lamellar Quartz, arranged in parallel planes.

Accidental elements: *Mica (passing to gneiss); blue Disthene; Epidote; Amphibole,* and *black Tourmaline.*

Leptynites which are rich in Quartz and Mica, may be regarded as the last degree of obliteration of granite.

8. **Harmophanite.** Cordier. This may be Orthoclase laminated in rocks, but it is more often a variety of Pegmatite, poor in Quartz. It fuses before the blow-pipe to a white enamel.

9. **Labradorite.** This name is given to masses, more or less fine-grained, derived from the Diallage or Hypersthene rocks, from which the elements, other than the Feldspar, disappear little by little. The Labradorite presents itself with its striæ and characteristic lustre. It is easily fusible before the blowpipe.

10. **Foyaite.** (*Foyait*). An aggregation of white, grayish, or bluish Orthoclase; reddish Elæolite, in hexagonal or rectangular sections, with a greasy lustre; and Hornblende in grains of a greenish-black. It is about the texture of Granite.

Accessory elements: *Brown Mica; Sphene; Pyrites.*

11. **Miascite.** A granular aggregation of grayish-white Orthoclase; Nepheline (a variety of Elæolite), with a greasy lustre; black Mica, mixed often with grains of a beautiful blue color, resembling Sodalite.

12. **Ditroite** (*Ditroït*). A granular mixture of Orthoclase, Elæolite, and blue Sodalite.

Accessory elements: *Oligoclase,* gray, or reddish-yellow; *Mica; Sphene;* and *black Hornblende.*

13. **Cordieritfels.** (Syn. *Dichroïtfels*). A granular mixture

not English [illegible]

of Cordierite, Feldspar, and Garnet, in veins in the Granite of Kriebstein (Saxony).

Accessory element: *Mica.*

14. **Kinzigite.** Garnet and Cordierite.

Accessory elements: *Oligoclase*, and *Microcline.*

15. **Gneiss.** Gneiss is composed principally of Feldspar, Mica, and Quartz. It is distinguished from Granite by its schistoide texture. Quartz, quite difficult to distinguish in some varieties, is, nevertheless, found in small grains, grayish in color, and somewhat worn; Feldspar, associated with it, differs little in aspect; Mica occurs in laminæ, often black, dividing the rock in parallel layers, plane or contorted or even folded in zigzags.

Notwithstanding this structure, the rock is not easily split into parallel layers. It is not easy to distinguish, mineralogically, Gneiss from schistose Granite; but, geologically, the latter is connected by insensible variations to Granites — having a granitoide texture, so to speak—which occupy the exterior limits; while, in the Gneiss proper, the entire mass is schistose. Further, Gneiss appears to contain, generally, only one kind of Feldspar. This is true at least of the gray Gneiss, composed of Feldspar, grayish Quartz and black Mica. In the red Gneiss of Saxony, which owes its color to Orthoclase, are also found Oligoclase and Albites. A great number of the latter are regarded as eruptive rocks.

Quartz appears to form about one fourth of Gneiss in general, and the Mica is in quite variable proportions from 10 to 30%.

Mica seems to be very abundant when the fracture is parallel to the surface upon which it is distributed; but when the fracture is perpendicular to this surface, it is seen to be in much smaller proportions. The Feldspar is often collected in reniform masses, here and there in the mass; and the Mica in nodules. The density is from 2.6 to 2.7. The proportion of the oxygen of the bases to that of the Silica, varies from 0.21 (Gneiss of Sweden) to 0.3 (Gneiss of Fribourg), and is some-

times as high as 4. The gray Gneiss contains 66% of Silica, and the red Gneiss about 75.

Accidental elements: *Talc* (*Protogenic Gneiss*), *Garnet*, *Hornblende* (*Syenitic Gneiss*), *Cordierite* (*Cordierite Gneiss*), *Graphite* (*Graphitic Gneiss*); *Calc-Spar*; *Oxide of Iron*; *Pyrites*; *Epidote*; *Sphene*; *Zircon*; *Spinelle*; *Sapphire*; *Disthene*; *Staurotide*; *Rutile*; *Molybdenite*, etc.

Certain varieties of Gneiss do not possess the property of complete lamination; they are split with difficulty and sometimes exhibit a somewhat fibrous structure. In general it forms inferior strata of earthy crystalline schists.

17. **Eurite** (*Petrosilex*, *Felsitfels* in part, *Hälleflinte*, *Hornfels* in part).—A compact mass formed of Potassic Feldspar of a grayish-white, yellowish, greenish, reddish, black, or brown color. The fracture is usually conchoidal, and resembles certain agates or chalcedony; but Eurite is always fusible; sometimes as much or even more so than Orthoclase itself, sometimes less so. The enamel which is produced by fusion is sometimes pure white, and sometimes marked with small spots of black or green. Eurite containing a great deal of Silica has, sometimes, a slightly vitreous aspect; is harder than Feldspar.

Certain varieties contain a little Mica which is ordinarily difficult to distinguish without the aid of considerable magnifying power. Eurite is found in stratified masses in the midst of gneiss or crystalline schists. They correspond, in part, to Hornfels.

18. **Quartziferous Porphyry**; (*Felsitporphyry*; *Porphyre Petrosilicieux*; *Porphyre euritique*; *Porphyre granitoïde*).

The small crystals of *Orthoclase* and *Oligoclase*, embedded in the matrix or paste, may be observed without the aid of a lens; also the crystals of *Quartz*. The density varies from 2.5 to 2.6. The proportion of the oxygen of the bases to that of the silica, varies from 0.16 to 0.259. The paste, of a dirty brown, or greasy red, is, in a fresh fracture, of a greenish, blackish, grayish-white, deep green, or brown color, rarely of a lavender blue.

There are two varieties: (1). It is always compact and having a conchoidal fracture. (2). It is scratched with difficulty by Quartz, and is less easily fused than Feldspar.

According to M. Delesse, it is richer in Silica than Orthoclase itself, and consists in a combination of Silica, Alumina and the bases of the rock. The second variety of paste is dull and colorless, having an unequal fracture, a fine-grained and crystalline structure. They are shown by the microscope to be fine crystals of Orthoclase and Quartz. The crystals of Orthoclase are white, yellow or flesh color; they have a pearly lustre upon the cleavage-faces, and a clearer color than the paste. Those of Oligoclase are hard, dull, of a white or gray color. They are mixed with the preceding—enveloping and surrounding them.


Fig. 21.

Feldspar sometimes passes to the condition of ochre, or else it disappears and leaves a cavity. The Quartz is in double pyramids of six faces, often slightly rounded; or in irregular grains with a vitreous, slightly greasy lustre. It is often full of minute cavities which contain liquid.

Accidental elements: *Mica*, in hexagonal tablets in prisms of a deep black, or sombre brown, or yellow; sometimes *amphibole hornblende* in small black prisms. Certain porphyries of Pénig (Saxony), from the middle of France, from the Vosges, etc., become true, pinitiferous porphyries, in which pinite occurs in crystals; the *Pinite* often decomposes and gives the aspect of bees-wax of a greenish-yellow color. Finally, porphyry containing, sometimes, crystals of *Pyrites*, of *Fer oligiste*, or *Talc* poorly represented, of *Diallage* and of microscopic Magnetite.

Some lithologists form a species in part of Granitoïde Porphyry; a variety in which the crystals are so numerous that they are not easily distinguished from the paste or matrix. The latter is often colored green by *Chlorite*, with which it is

intimately mixed. It often includes *Hornblende*, also, which perhaps gives rise to the green color; it has a crystalline structure, and the ordinary elements of granite may be distinguished with a low magnifying power. Porphyries form mountains of a savage aspect, with steep sides and ragged crests, often bristling with sharp pinnacles.

Varieties of structure and texture: *Quartziferous Porphyries properly called.* Masses divided into hexagonal prisms, and right or oblique parallelopipeds. *Schistose Porphyries.* The Quartz in this, is in veins, in their parallel laminæ; plane *(Papier Porphyry)* or undulating *(Ligniform Eurite).* Perhaps the schistose appearance arises from the different colored parallel bands.

Cellular, or *Porous Porphyry* with amygdaloidal cavities. *Oolitic* or *Spherulitic Porphyry* is in rounded masses from the size of a walnut to that of the head; the centre of which is filled with agate or some other crystallized substance. With this variety is classed Porphyre Pyroméride (P. orbiculaire, P. Napoleon) of Corsica, which consists of an Euritic paste, enclosing globules of a radiated texture, in which Orthoclase and Quartz may be more or less easily distinguished.

Dikes of Porphyry abound in the carboniferous rocks. Their outcroppings, numerous still in the Permian, become more or less rare in the upper formations; they appear to terminate in the Cretaceous. Sometimes, at the point of contact with the enclosing rock, Porphyry exhibits a schistose structure.

19. **Porphyries poor in Quartz or non-Quartziferous** *(Quarzfreier Orthoklasporphyr).*—Density from 2.63 to 2.76. The proportion of the oxygen of the bases to that of the Silica is 0.3. The rock consists of a matrix of compact Feldspar enclosing crystals of Orthoclase, Oligoclase and Albite.

Its exterior characteristics only differ from those of Quartziferous Porphyry in the absence of Quartz crystals. The paste, which is easily fused, is generally of a dark color, more or less porous, inclining to a dirty blue-violet, a reddish-gray, a bluish

brown or a chocolate-brown color. Often with the Feldspar is a deep brown or reddish-green Mica.

20. **Argilophyre** belongs with the non-quartziferous porphyries. It has an earthy aspect, clayey, porous, full of minute cavities, easily scratched with a steel point, and appears to owe its properties to a change, partial at least, in the Feldspar. It is fusible only on the edges; is usually massive, and sometimes schistoide. It passes into Pechstein or Retinite.

21. **Brecciated Porphyry** *(Porphyry Breccia. Porphyritic Breccia)*.—In certain cases the mass of Porphyry has been broken during its uplift, and the angular fragments have been reunited by an euritic cement, more or less abundant, of a brown, red, bluish or greenish color. The rocks of this nature cover the Porphyries proper, and sometimes alternate with them. At the point of contact of Porphyries and the encasing rock, a débris of angular masses has been formed by the abrasion during the uplift.

22. **Porphyritic Conglomerates.** *(Porphyry Conglomerate)*.—Porphyry in rounded fragments, united by a cement of which water has been the solvent. They may be classed for the most part with Psephites.

23. **Euritine**. Cordier. Feldspathic Sandstone. Clay. A sort of sandstone composed of very fine opaque and fusible grains of Feldspar and siliceous cement, mixed or not with clay or lime. The colors vary from a yellowish-gray to green and violet, sometimes giving the rock a striped appearance. Some varieties are mixed with Chlorite.

Euritine forms beds in different sedimentary formations. It is often found in the neighborhood of Porphyries. We may class here, also, *Hornfels*, Feldspathic or micaceous sandstone of microscopic elements confusedly mixed, but, here and there, distinct.

24. **Oligophyre.** Porphyry with Oligoclase (Porphyrit, G. Rose).—The paste is of a green, brown, or red color; some-

times bluish or smoky gray; fusible with difficulty before the blow-pipe.

Essential Crystals: *Oligoclase*, white, yellowish, or reddish, nearly opaque, containing 62% of Silica.

Accessory Crystals: *Amphibole*, laminated or acicular; *black Mica*, in scales; *black Augite*.

Varieties: *Oligophyre* proper. Proportion of Silica 61 to 64%. Brown paste; conchoidal fracture; very large striated crystals (at Boulouris).

O. quartziferous. The preceding with Quartz in dihexahedrons.

O. amphiboliferous. Crystals of Amphibole in smaller quantity than Quartz and Oligoclase.

In the Red antique Porphyry, according to M. Delesse, the Feldspar, of a white, reddish, or rose color, is allied to Oligoclase rather than to Labradorite, and contains 59% of Silica and 55% of Lime. The paste is red (64% of Silica), or violet (Silica 62%). The amount of peroxide of Iron in this paste is about 8%, and the density 2.763. Besides Feldspar it contains Hornblende in small scattered crystals, and Quartz in irregular veins.

O. with chlorite. Syn. *Protogenic Porphyries*. The Porphyries of Lessines and Quenaast (Belgium) are composed of a green paste, colored by chlorite, in which crystals of Oligoclase may be discerned, a little Hornblende, and carbonates of Lime and Iron. In the Porphyry of Deville (Ardennes) the Feldspar exists in large crystals.

O. Micaceous. Porphyry of Schirmeck (Vosges), with crystals of Oligoclase and plates of Mica. Density 2.686. Proportion of Silica, 65.74% (Delesse).

O. Augitic. Porphyry of Chagey. Very strongly magnetic. Paste of a deep green. Density 2.74; fusible, and has 61.71% of Silica.

Accessory minerals: *Cubic Pyrites; Epidote; Ferruginous Chlorite.*

Tridymite has been discovered, by aid of the microscope, in some varieties of Porphyry.

GROUP OF TRACHYTIC AND VITREOUS ROCKS.

25. **Trachytes.**—They differ only from Eurite and Euritic Porphyries by the characteristics of texture. They are composed of grains, often fine, enclosed with Sanidine or vitreous Feldspar, leaving spaces between them, which gives them a porous texture, an irregular fracture, an uneven aspect and a rough feel. The lustre is dull, often becomes quite argillaceous in certain varieties, and is semi-vitreous. They contain from 60 to 62% of Silica and more Sodium than Potassium.

The dominant colors are yellowish-white, greenish-white, reddish, gray; rarely bluish. The essential Feldspar is *vitreous Orthoclase (Sanidine)*, of a white or yellowish-white color, a brilliant lustre, but is not as limpid as Adularia, by reason of its interior fissures, which are observed to be more and more numerous as we magnify them. They often present themselves in large tabular crystals flattened on the face.

Porphyritic Trachytes. The following may be found in the Trachytes as accessory minerals: *Oligoclase Hornblende*, in short prisms and brilliant black crystals; brown or black *Mica* in hexagonal laminæ *(Micaceous Trachyte)*; *Magnetic Iron*, or *Titanic Iron Ore*, 1 to 2%; and, finally, *Sodalite* and *Sphene* as accidental elements.

These are the characteristics of the Trachytes proper. Sometimes the proportion of Oligoclase is the same as in Sanidine (Trachytes of Drachenfels, *Sanidine Oligoclase-Trachite*, of Roth, gray, brown; in the mass of which the two species of Feldspar appear slightly distinct, one from the other, under the form of crystals or grains, and in which the proportion of Silica is about 66%).

Domite is a Trachyte of Puy de Dôme; friable, having an earthy aspect, gray, dull, in which crystals of Feldspar may be

distinguished, which are large and brilliant, and which hold Silica in the same proportion as the true Trachytes; but several lithologists have discovered, by the aid of the microscope, numerous grains of quartz which assimilate them to the Trachytes of the Drachenfels. The *Tephrines* are Trachytes, the paste of which has become tarnished and dull by alteration. Ex. Tephrine of Hungary (containing Opal).

Finally, there are other varieties also curious:

Globulous Trachytes; Spherulitic Trachytes, the paste of which is full of minute cavities; *Brecciated Trachytes* composed of angular pieces of this rock, of different colors, in a paste of the same nature.

26. **Sanidophyres, or Trachytic Porphyries.**—When the crystals of Sanidine, enclosed by the paste of Trachyte, are very numerous, the rock becomes a true Porphyry; certain varieties have a compact texture, a conchoidal fracture, and an appearance almost identical with quartziferous Porphyry, but which may be more porous than the latter. In a collection, they are very hard to distinguish; but, upon the ground, one may always find them associated with the Trachytes, with such characteristics as will enable him to distinguish them readily.

The Trachytic Porphyries are of a yellowish-white, greenish, or clear reddish-gray color; rarely blue. They contain, ordinarily, Quartz in grains or limpid crystals.

Accessory minerals: Mica and Garnet are not very abundant. Oligoclase is also rare, except in the Trachytic Porphyry of Esterel. Silica sometimes forms 78% of the whole. The density varies from 2.44 to 2.63. The compact masses often have the appearance of bees-wax and pass to *Retinite.* In a certain number of varieties, on the contrary, the pores become very large and take the form of blisters or cells with wrinkled sides. These Trachytes sometimes have the appearance of siliceous mill-stone, from which they differ in being fusible before the blow-pipe.

The Trachytic Porphyries are sometimes *schistoide,* on ac-

count of the division of their tabular crystals of Sanidine along parallel planes; or *zonaire*, caused by the distribution of different colors which some varieties present. These rocks have sometimes the aspect of granite.

The Trachytes are tertiary or post-tertiary. Those of Hungary are cretaceous, according to Beudant. They have the appearance of domes, and stand in groups in the midst of layers of older rocks. They also fill the irregular fissures in the rocks under the form of dikes and veins. They exhibit sometimes a prismatic division analogous to that of the Porphyries. They exhibit themselves in layers on the surface of the ground, and in this case they have acted after the manner of Basalts. Many of these streams proceed from orifices which preserve, quite accurately, volcanic characteristics, so that the rocks merit the name of lavas. They are always more or less full of cavities. Often the upper and lower surface of such layers have a spongy aspect. They are semi-vitreous, full of holes, and porphyritic (Mont Dore). To this variety, in the description of rocks after Cordier, has been given the name of Feldspathic Necrolite.

27. **Trachytic Cinders.** (Syn. Spodite, Cordier).—These are formed from the disaggregation of the Trachytes, and matter projected from volcanoes at the time of the eruptions of Trachyte or Phonolites (Cascade of Mont Dore).

28. **Andesites.**—This name is given to Trachytes, more or less porous, often granitoid, which differ from the Trachytes proper by the absence of Sanidine. The mass consists of a paste of vitreous Oligoclase, fusible before the blow-pipe, and having nearly 60% of Silica. It is not rare that the crystals show themselves in the paste.

The Trachytes of the Andes often have a granular texture.

Accessory minerals: *Hornblende, Augite, Magnesite, Mica.*

Varieties: (1) Andesites enclosing Hornblende. Ex. Andesites of a black, deep gray or green color, of Siebenberg, enclosing, sometimes, large crystals of Hornblende and Oligoclase

of a grayish or greenish color. These rocks often contain Quartz, and then their proportion of Silica exceeds sometimes 70%. Mineralogically, these are Diorites.

(2). Andesites enclosing Augite (*Augit-Andesite*, Zirkel, or *Trachydolenites*). The Augite in this is exhibited in crystals or visible grains.

Accessory elements: *Hornblende*; *Magnetic Iron*. The density of this rock is about 2.8. It is reduced to 2.7, however, when the Silica is about 64%: *Augit-Andesites with Quartz*, Zirkel.

Ex. Trachytes of the Andes; Peak of Teneriffe; Hecla, in Iceland.

Andesites exhibit the same characteristics of development as Trachytes. They are divided sometimes, into enormous many-sided pillars. In the Andes they form large elevated cones.

29. **Phonolite** (Syn. *Petrosilex fissile*).—Compact masses of a greenish-gray, or yellowish color, more or less deep, ordinarily separated into slender sonorous plates. They are the result of an intimate mixture of two parts; one formed of Sanidine, insoluble in acids; and the other of Nepheline mixed with Zeolites, soluble in hydrochloric acid.

In the Phonolites of Bohemia have been discovered, by the aid of the microscope, great quantities of Nepheline in short hexagonal prisms, and Noseane Silicate, soluble to a jelly in hydrochloric acid. Sometimes may be seen with the naked eye, tabular crystals of Sanidine flattened along the cleavage-face g^1, and parallel to the planes of division of the rock. Phonolite fuses before the blow-pipe to a grayish or greenish glass. In the open tube it yields water.

Accessory elements: *Hornblende*, in black, acicular prisms; *Sphene*, yellow or reddish; *Mica*, brown or silver-white; *Zeolites*. The density varies from 2.5 to 2.6.

Varieties: Phonolite proper (schistoide). Phonolite non-schistoidal, homogeneous or porphyroidal. Phonolite spotted, containing Noseane.

The Phonolites present, in masses, the same method of development, and the same aspect as Trachytes, but the peaks are more isolated, and at the same time more durable and sharper. They often traverse the Trachytes.

30. **Obsidian.**—This is a Trachyte in a vitreous state, and has a high degree of lustre, a conchoidal fracture, and a brittleness equal to that of glass. The most common colors are blackish-green, velvet-black or brown; very rarely gray or greenish-gray. Sometimes Obsidian becomes iridescent. When a splinter is placed before the blow-pipe, it glows with a brilliant light. The edge of the fragment swells up into a glassy globule which resembles solidified froth.

Usually, the vitreous mass of Obsidian encloses numerous microscopic crystals of Feldspar, which, in the phosphoritic varieties, become visible to the naked eye. Certain varieties pass into pumice full of cavities. The others are formed of a mass of small capillary filaments (*Obsidienne Filamenteuse*). The name of *Spherulitic* Obsidian has been given to those which contain globules the size of a walnut or smaller, composed of fibres collected together and radiating from the same centre.

Analysis of the Obsidian from the Peak of Teneriffe by M. Deville, gives Silica, 69.71; Alumina, 19.23; Oxide of Iron, 5.48; Oxide of Manganese 0.30; Lime, 0.58; Alkalies, 14.70. Obsidians contain about 80% of Silica. The density is often about 2.4.

31. **Pumice.**—This differs from Obsidian by its cavities, with which it is completely perforated, and which give it the appearance of a fabric of fine glass threads, parallel or intercrossing, leaving between them irregular cavities. The colors vary from white to yellowish-gray and greenish. It is rough to the touch, may be scratched with a steel point, is fusible before the blow-pipe to a white enamel, and has a density of from 2.37 to 2.53. It often contains water mixed with hydrochloric acid.

Pumiceous Lapilli. Pumice frequently appears in the midst

of Trachyte as one of its varieties of texture. It is one of the products of volcanoes, mostly in the form of lapilli or cinders.

32. **Retinite.**—*Pechstein, Pitchstone, Pierre de poix, Perlites.* A vitreous or semi-vitreous rock, translucent on the edges, and brittle. It has a greasy lustre; the fracture is slightly conchoidal and scaly; its aspect is that of pitch or resin, or an enamel with a lustre more or less bright; the colors vary from olive-green to yellowish-brown; sometimes it is black, or red, on account of a mixture of oxide of iron. It is easily fusible before the blow-pipe, setting free vapor of ammonia almost always with intumescence.

Retinite contains generally more Silica than Orthoclase (about 72%) and less alumina; the proportion of water varies from 5 to 10%. It is not so hard as Orthoclase; density, above 23.

It often becomes porphyroidal; it then encloses crystals of Orthoclase large enough to be visible to the naked eye; also grains of Quartz and sometimes Mica: especially when near porphyritic formations. They are often globuliferous and their globules are composed of Feldspar, *Perlitic Retinites.*

In some varieties (*R. Zonaires*) may be seen zones which have alternately the appearance of glass and of porcelain. In some other varieties, the vitreous mass exhibits portions which have the appearance of compact Feldspar, and resemble Breccia. (R. Brechoide). Finally, certain other varieties exhibit amygdaloidal cavities filled with agate, chalcedony, etc.

The Retinites thus defined are feldspathic Porphyries, or quartziferous Trachytes in a vitreous state, and the passage from one to another may often be observed. The Porphyries present the appearance of agates or enamel more frequently than the Trachytes. This distinction is, in general, not marked.

According to Zirkel, the Retinites of the Trachytes enclose a large number of microscopic corpuscles, *Belonites,* and cavities, visible under a slight magnifying power.

33. **Perlites.**— Some lithologists have classed in one particular group, all the vitreous rocks composed, totally or in

great part, of globuliferous or polyhedral elements. The globules are formed of fine laminæ, membraneous, with a greasy lustre, overlying like the coats of an onion, or presenting an undivided mass which resembles glass or porcelain; they are sometimes grouped confusedly, and, sometimes, by mutual pressure have taken a polyhedral form. In certain cases they are separated from one another in the center of a vitreous paste which resembles an enamel. This paste contains sometimes, crystals of Sanidine or Mica; sometimes Opals, grains of Obsidian (Marékanite), microscopic filaments analogous to those of Obsidian, and finally Spherolites.

In the spherolitic Perlites, the Silica reaches 70 and 80%, and their density is much greater than that of Retinite, with which they are nevertheless classed, by reason of their common origin and the analogy of their general composition.

TUFA, TRACHYTIC AND PUMICEOUS CONGLOMERATES.

Fragments of pumiceous cinders or Trachytes, ejected from volcanoes, have been carried by the wind to considerable distances, and often again transported, modified, cemented by the water of the atmosphere or the earth. There have resulted from this action, masses of a clayey character, which are called *Tufas, trachytic, phonolitic, pumiceous conglomerates.*

34. **Trachytic Tufa.**—Friable or compact rock; grayish or ochre-yellow; earthy; having the appearance of volcanic mud solidified; enclosing, sometimes, crystals of Sanidine, Mica, etc.

35. **Breccia, Trachytic Conglomerates.**—Angular fragments; rounded pebbles of Trachyte, mixed often with débris of different rocks, cemented by a paste which consists of Trachytic Tufa.

36. **Phonolitic Tufa.**— Débris of Phonolite mixed with fragments of crystals of Sanidine, Mica, Hornblende, and Magnetic Iron ore, united by an earthy paste which effervesces in acids.

37. **Pumiceous Tufa.**—Pebbles of Pumice, grayish, mixed with foreign substances (Mont Dore, France).
with foreign substances (Mont Dore, France).

38. **Pumice Conglomerates.**—Fragments of Pumice agglutinated with débris of Trachyte or Obsidian, by a Pumice Tufa more or less apparent.

39. **Volcanic Trass** (Variety of pumiceous conglomerate).—These are earthy rocks, dull grayish, yellowish, or brownish; more or less compact, formed of a pumiceous dust, decomposed, which encloses fragments of Pumice, Argillaceous schist, crystals of Feldspar, Mica, and carbonized wood. In the closed tube it yields water often containing ammonia, chlorine and sulphuric acid. It fuses with difficulty to a grayish enamel. It forms the bed of the river Rhine, where it is used as a hydraulic cement.

According to Cordier, the paste of volcanic Trass seems to be trachytic rather than pumiceous, and the cement consists of hydrosilicate of Alumina, arising from the decomposition of the cinders, and sometimes of aluminite. Cordier recognizes rocks arising from the decomposition of Pumice or pumiceous cinders, calling the first *Asclerines* and the latter *Alloites*.

CHAPTER II.

PYROXENIC AND HYPERSTHENIC ROCKS.

40. **Dolerite.**—A granular mixture, granitoid in texture, very brilliant on the fracture surface, having a somewhat spotted appearance. It is composed of *Labradorite* of a clear gray color in depressed crystals; *Augite* of a greenish-black color; and a small amount of *Magnetite.*

Accessory elements: *Calc-spar; Spathic Iron.* Boiled in hydrochloric acid, this rock yields 40% of soluble ingredients; it effervesces for a short time.

Accidental elements: *Nepheline; Analcime* in cubo-trapezohedrons, often limpid; *Melanite* in black rhombododecahedrons; *Mica; Amphigene; Cubic Pyrites; Hornblende,* etc.

Varieties: *Granitoide; Dol. Porphyritic; Dol. Mimosite; Dol. Anamesite,* a fine-grained variety having a brilliant crystalline fracture, and passing to Basalt; *Scoriaceous Dol.* (Doloritic Lava). The lava of the island of Fogo, one of the Cape Verd islands, contains, according to M. Ch. Saint-Claire Deville, 54% of Labradorite; 19% Augite; 19% Olivine; 7% of titaniferous magnetic Iron. Its density is 3. That of Etna (eruption of 1865) has a density of 2.738 and contains 49.27% of Silica. *Amygdaloidal Dolorites;—Dol. with Analcime* (*Cyclophyre*). Gray rock, porous and containing crystals of *Analcime.*

41. **Basalts.**—Volcanic rocks, homogeneous, tenacious, of a bluish-black or gray color, generally dull, more or less porous, and more or less strongly magnetic; harder than steel. They are made up of grains, distinguished by aid of the microscope. The density is usually about 3; and the proportion of Silica is about 45%. Oxide of Iron from 6 to 22%. In the open tube it gives from 2 to 4% of water. They are easily fusible.

In a celebrated memoir, Cordier first defined the mineralogical composition of Basalts. These masses consist of a mixture of grains, which are extremely fine, of Labrador Feldspar, Augite, and a certain relatively small quantity of magnetic Iron, more or less titaniferous.

It very frequently encloses nodules of vitreous grains of Peridot of a yellowish-green or grayish color. Like the Melaphyres, the Basalts *comport* themselves as true Traps, and display themselves upon the surface in vast terraces one above the other; also they appear as great walls or masses of ruins. But in many cases, basaltic craters have ejected lava of scoriaceous texture, cinders, and scoriæ, like those of actual volcanoes.

The Basalts, like the Trachytes, cover with a dome-shaped mass, the passage by which they have been ejected. Generally the Basalts with their tufas and conglomerates are of the tertiary period. They traverse all the stratified rocks and all eruptive rocks anterior to this age. The Basalts of central France appear to be later than the Trachytes of the same region. They generally appear in the form of prismatic columns, often rising vertically to considerable heights and are sub-divided transversely by joints, as at Fingal's Cave and Giant's Causeway.

Zirkel undertook the microscopic study of Basaltic rocks in 1870. He discerned in a large number, a vitreous substance of a brownish-yellow color, sometimes gray or colorless. This matter plays the part of a cement to the crystalline grains. It represents the paste of the Basalts, the residue of the original magma, remaining in the amorphous state after the separation of the crystals.

In some Basalts this paste is only demi-vitreous made up in part of black or brownish-black crystalline needles, to which Zirkel has given the name Trichites.

Augite, often in crystals of a bright black color, plainly visible to the naked eye, becoming brown, more or less yellowish in thin sections, and exhibits colors in polarized light. It ordinarily

offers the following forms (Fig. 22). It often contains much smaller crystals of Apatite and Magnetic Iron; also cavities empty or filled with liquid; perhaps compressed carbonic acid. Similar cavities are found in grains of Peridot.

Fig. 22.

Feldspar is crystallized in elongated lammæ which are subdivided into longitudinal bands, alternately colored blue and gray, or with lively shades varying in polarized light. Zirkel observes that this Feldspar is not attacked by acids.

Magnetic Iron is found in the form of irregular grains or crystals arranged in regular rows, disposed in files, or in interlacing, irregular rows, more or less regular. A great number of Basalts contain *Nepheline* and *Amphigene.*

Accessory Elements: *Apatite* in elongated, hexagonal prisms; *Hornblende*, black or brown, traversed by parallel fissures; *Magnesia; Mica*, visible under the microscope.

Accidental minerals: a great number of Zeolites (*Chabasite, Analcime, Harmotome, Stilbite*, etc.). *Calc-spar, Aragonite;* nodules of *Hyalin Quartz*, and *Agates;* small irregular masses of *Hyalite* in the cavities; *Blue Sapphires, Cordierite; Black Pleonaste; Hyacinth Zircon, Pyrites*, etc., mixed with the mass. Finally the Basalts of the county of Antrim, Ireland, contain sulphate of copper in solution, and owe this property, without doubt, to metallic Iron intimately mixed.

Varieties; common Basalt.

B. with fragments of Peridot. Peridotite of Cordier. The rock contains an aggregate of polyhedric or rounded grains of a green or yellowish-green or blackish-colored Peridot mixed with Enstatite.

B. Amygdaloidal has large cavities in which may be found

beautiful crystals of Zeolite with Chalcedony, Calc-spar, Arragonite, etc.

42. **Gallinace** (Syn. *Trachylite, Vitreous Basalt*).—Vitreous or semi-vitreous masses, sometimes stratified, of the color of pitch, bluish or brownish, having the appearance of earth or enamel, but less durable than Feldspar, easily fusible to a colorless bead; speckled with black and often scoriaceous. Density, 2.56 to 2.7. Silica, 56% in the Trachylite of Hanover.

Scoriaceous Basalts ; Basaltic lava.

Stratiform Scoriæ. The exterior crust as well as the lower portion, which was the first to be ejected, often has a scoriaceous or porous texture, homogeneous or porphyritic, and more or less vitreous. The blocks ejected during the eruption have irregular forms. They are contorted, and divided into cells by partitions (*Cloisonées*).

Some by projection through the air, have, by reason of a rotatory motion, acquired an ellipsoidal form, with elongated and twisted extremities (*volcanic bombs*). They are generally red on the exterior and rich in Peridot, the Iron of which is generally in the state of peroxide.

Lapilli Scoriæ in small fragments, which have fallen in showers about the crater.

Basaltic Cinders.—Pulverulent scoriæ. Those of the eruption of 1843, were of a clear gray color, and contained 46.31 % of Silica; 16.85 Alumina; 9.85 Ferric peroxide; 4.43 Ferric oxide; 10.28 Lime; 5.44 Magnesia; 1.41 Potassa; 3.34 Soda; 2.21 Sulphuric acid; 0.52 of Hydrochloric acid, Ammonia and Gypsum.

Basaltic Scoriæ, in layers or in the state of lapilli or cinders, more or less decomposed, are employed in the manufacture of hydraulic cement under the name of Puozzolani. Ex. The catacombs of Rome are excavated in this rock. *Laterite* is a rock of this class and forms a deposit between dikes of Basalt in the West Indies.

43. **Nephelinites.**—Rocks with a compact or granular tex-

Gallinace and [illegible]
[illegible]

ture—all having the appearance of Basalts and differing only by the substitution of Nepheline for Feldspar.

Nepheline is found in six-sided prisms and is recognized by its greasy lustre, by its color, which is yellowish-white, sometimes greenish or reddish; its fusibility before the blow-pipe; and its gelatinous deposit in hydrochloric acid which finally dissolves entirely.

Varieties: *N. Granular; N. with fine grains; N. compact; N. with Amphigene (passing to Amphigenites).* A great number of the lavas of Lake Laach enclose in their cavities crystals of Nepheline, Haüyne and Zircon.

44. **Amphigenites.**—Compact rocks, often porous, of a clear or deep gray or reddish color. These are Basalts in which the Feldspar is replaced by *Amphigene.* Throughout the paste are distributed grayish-white crystals, either of *Amphigene* in trapezohedrons or small crystals of *Augite.*

Amphigene is easily recognized by its almost spherical form and its complete decomposition, with a deposit of Silica in hydrochloric acid; and its fusibility before the blow-pipe.

The prisms of Augite are small and of a grayish or greenish color. Amphigenites almost always enclose more or less Nepheline and often Haüyne.

Accidental minerals: *Breislakite; Melilite; Melanite; Mica; Sodalite; Copper Chloride.*

Varieties: *Compact Amphigenite* (few apparent crystals); *Porphyroidal Amphigenites* or *Leucitophyre; Scoriaceous Amphigenites,* Lavas with Amphigenite (Vesuvius).

In certain Lavas of Vesuvius, Amphigene and Sanidine have been distinguished as essential elements.

45. **Hauynophyre.**—Lavas of a deep gray or blackish color which are allied to the basaltic lavas, only the Feldspar is replaced in part by vitreous Haüyne in rhombohedral dodecahedrons, ordinarily blue, sometimes white by alteration.

46. **Augitic Rocks.**—Described by Sterry Hunt of Chatham, Canada. Rock formed of granular Augite.

Accessory elements: Tourmaline; Amphibole, etc. *Coccolite.* Masses formed of grains of Pyroxene, sometimes white (having a base of Lime and Magnesia), sometimes green or blackish (base of Lime, Magnesia and Iron).

47. **Eukrite.**—Granular aggregation of very distinct elements which are, (1) White Anorthite, entirely soluble in hydrochloric acid; (2) Augite of a grayish-green color. This rock forms a vein in the carboniferous limestone in the district of Carlingford, Ireland. The proportion of Silica is 47.52%, and its density is 2.757. (Haughton).

48. **Peperine** (Syn. *Tufa; Volcanic* or *Basaltic Tuff*).—A mass of a cinder-gray or of a yellowish-brown color, sometimes reddish, or of intermixed colors; earthy, brittle, porous or cellular, recalling Wacke by its appearance, and enclosing fragments of basaltic rocks with their crystals broken or intact, Augite, black Mica, Magnetite, Amphigene, Zeolites; sometimes, also, fragments of Calc-spar or Dolomite. When the angular fragments of Basalt are dominant, the mass is called *Basaltic Breccia.* These breccias occur intermingled with the Basalts. In the Basaltic conglomerates, the fragments are rounded.

Tuff with Palagonite.—Tufas which enclose a more or less large quantity of granular Palagonite. Palagonite is a hydrated silicate of Alumina, Iron, Lime, Magnesia, Potash, and Soda; making a jelly in hydrochloric acid; fusible to a black magnetic bead before the blow-pipe. It is of a yellow color, often brown or black. Density 2.5; hardness, from 4 to 5. It has the appearance of amber or rosin.

Altered basalts, covered at first with an ochre-brown crust, intersected with numerous cracks owing to a chemical alteration, which reduces them, first, to a muddy gravel full of Augite crystals; and, finally, to a grayish and fertile clay.

49. **Ophitone** (Syn. *Diabase, Mélaphyre grenu*).—

Comprised under this denomination is a very important group of rocks which bear the same relation to the Melaphyres as the Dolorites to the Basalts. These, like the Dolorites, have a gran-

ular texture, and are a mixture of *Labradorite* and *Augite*, ordinarily accompanied by *Magnetite*. They differ, mineralogically, by their accidental mixture. The Labradorite forms tabular, striated crystals, with a decided cleavage, of a grayish-white or green color. The Augite is in rather short prisms, often with very distinct cleavages. In the rock called *Porphyry* of Ternuay have been discovered bottle-green crystals of Pyroxene and hydrated Feldspar, with a greasy lustre, to which M. Delesse has given the name of Vosgite; the mean density of this rock is about 2.84.

Accessory elements: *Magnetite, Ferruginous Chlorite.*

Accidental minerals: *Pyrites, Cat's eye, Epidote, Asbestos.*

The proportion of Augite is generally less than in the Melaphyres. Silica varies from 45 to 53%. The density is about 2.8; it however reaches 2.93 in a number of fine-grained varieties which form part of the rocks of Sweden and Ireland, confounded with many others under the name of Trap.

Varieties: *O. with medium sized grains; O. with fine grains; O. Schistose*, of a gray, green, or blackish color, often colored green by chlorite, becoming yellow in hydrochloric acid; *O. Calcareous*, containing a great many crystals of Calc-spar, soft enough to be scratched by a steel point, very easily fusible; *O. Amygdaloidal*, with cavities filled with Calc-spar.

Often the Ophitones have a shagreen surface, the cavities of which are caused by the disappearance of the Feldspar. The complete decomposition of the Labradorite causes the disintegration of the rock and the production of a marl mixed with black grains of Augite.

50. **Melaphyres** (Syn. *Ophite*, Cordier; *Porphyres noirs; Porphyre vert antique; Toadstone; Porphyre diabasique ou augitique;* partie des Trapps et des Grünstein).—Rocks of which the color is often black, but still more often green. They are composed: (1) Of a fine-grained paste, compact, tenacious, generally black in color when the fracture is fresh, but changing to brown or reddish by alteration; often magnetic. (2) Crystals of

Augite and Labradorite of a greenish-white color, having a poorly defined contour. Generally the rock has combined with it, calc-spar, some magnetite, and chlorite, which latter colors it green.

In hydrochloric acid it effervesces and becomes yellow. Before the blow-pipe, it loses its water and becomes very clear; it fuses more or less easily into a globule of a bottle-green color. The density varies from 2.7 to 3.

Accidental minerals: *Pyrites; Quartz* and its varieties, *Amethyst; Cat's eye; Chalcedony*, distributed not in a homogeneous manner, but here and there throughout the whole in small crystalline masses; *Epidote; Axinite; Green earth; Hornblende; Mica.*

Varieties of composition:

(1) *Melaphyres* in which the proportion of Silica is inferior to that of Labradorite (53%). A number of the Melaphyres of Norway (48.76%). Melaphyres of the valley of Fassa, Tyrol, (45.65%; density 2.71 according to Streng).

(2) *Silicious Melaphyres*, in which the proportion of Silica is greater then 53%. Certain Melaphyres from the environs of Christiania (58.5%, after Kjerulf). Melaphyres from the left flank of Mühlenthal (57%). Amygdaloidal Melaphyres of Faucogney (54.42%; density, 2.906, according to M. Delesse). Black Melaphyres from Elbingerode, Hartz (57 to 58%).

Several eminent lithologists have thought that in the second group, the paste is a base of Oligoclase. But a certain number of Melaphyres, analyzed under the microscope by Zirkel, have shown in their mass, a more or less large quantity of vitreous matter, accompanied or not by needles of what is called Trichites; hence, probably, the great proportion of Silica.

M. Durocher remarked a long time since, that the paste of porphyries is not, in general, richer in silica than their Feldspars; and M. Delesse regards it as a magma which has not been able to crystallize.

Varieties of elementary composition:

(1) *Mel., poor in Augite* (*Labrador porphyry*). A greenish-gray or blackish paste, often containing Calc-spar. Fusible with difficulty. Crystals of Labradorite often very large. Examples: *Porphyry of Belfahy*, Vosges, a paste of a green color more or less deep, Magnetic, (53.45% of Silica, 75% of Labradorite; proportion of water 2.5; density 2.775); *old green Porphyry* with an olive-green paste; certain Melaphyres about Christiania.

(2) *Melaphyres rich in Augite. Black paste.* Mel. of the valley of Fassa have large crystals of Augite and striated pearly Labradorite (*Basic or Augitic Melaphyres* of M. de Lapparent).

51. (3) *Melaphyres with Ouralite* (*Uralitic Porphyry*). A paste of a greenish-gray or blackish-green color, with crystals of Ouralite of a greenish-black or brownish color. The nature of this paste is not known.

Varieties of texture: *Amygdaloidal Melaphyres. Melaphyre Tufas.* An earthy mass of a grayish-green or blackish color forming a species of mud or mire enclosing fragments of Melaphyre which are angular in the Breccias and rounded in the Conglomerates. They form beds in the Devonian earths in the neighborhood of rocks which furnish their elements.

Ophitone Melaphyres and their Spilites are eruptive rocks which fill great fractures in the earth's crust. Often these rocks are introduced laterally between the strata which they traverse, as if they were contemporaneous; but after having extended branches in many directions, the main trunk or column crops above the surface and is extended in layers upon the surface. In Derbyshire, where they are called *Toadstones*, they may be seen thus injected between the strata of carboniferous limestone and millstone grit. Often several successive layers, issuing from the same centre of eruption, have been superposed—the edges of the layers resembling steps of a gigantic staircase. This formation gives them the name *Traps* in the north of Europe. They are often found as veins in narrow crevasses. In the neighbor-

hood of Christiania, the Melaphyres appear in the Silurian rocks. In England, they are widely distributed in the Carboniferous. In the Ural district, they occur in the Devonian rocks. In the Hartz Mountains, they are extensive dikes, rich in amygdaloidal varieties, and are between the Carboniferous and Permian systems.

Spilites. Under this name may be classed Basalts, Dolorites, Ophitones, and Melaphyres, which possess analogies in appearance and amygdaloidal structure.

52. (1) **Spilites of the Melaphyres.**—These are full of holes of ellipsoidal shape nearly always filled with nodules, partly earthy and partly crystalline. These nodules are composed of green earth (*Delessite*), of calc-spar, and sometimes of chalcedony. The paste of the Porphyry which serves as a nucleus, often shows signs of alteration, which is indicated by a brownish-red color and an argillaceous odor. In the Melaphyres of Oberstein and Idar on the borders of the Nahe; in those of the quarries of Salto, near Montevideo, the cavities are often larger than the head, and are lined with incrustations of agate and amethyst. In certain nodules of agate, the channel by which the siliceous matter entered may be recognized.

Zeolites, so common in the cavities of the Basalts, are very rare in the Melaphyres. These rocks are sometimes stratiform (*Schalstein* of Germany).

53. (2) *Spilites of the Basalts (Amygdaloidal.)*

Wackes. This name is given to common Basalts and Melaphyres at a certain stage of decomposition.

54. **Melaphyre Wackes.**—Vesicular paste of a green or brown color, an earthy appearance, and of a loose texture; it often encloses crystals of Feldspar and Augite. This stage of decomposition is observed in many of the Melaphyres and especially their Spilites.

55. **Basaltic Wackes.**—Compact earthy masses, of a greenish-gray color; sometimes brownish or reddish; having an argillaceous odor and stick to the tongue; in which have been

discovered plates of Mica; crystals of Augite; Zeolite and Hornblende; grains of Magnetite and Peridote, which have become red by alterations; the cavities of which are often filled with crystals of Calc-Spar, Green earth, Chalcedony, etc. In masses or blocks in the Peperines.

The clays arising from the complete decomposition of the Basalts and Melaphyres, are not so easily distinguished from each other. They are very rich in Magnesia and enclose crystals of Feldspar and Augite, and grains of Magnetite.

Euphotide and *Granitone.*—These two varieties of rocks enclose a material of a grayish-white, greenish,or sometimes violet color, of a slightly greasy lustre, often striated. It fuses with ordinary facility before the blow-pipe to a white enamel. It is attacked by hydrochloric and sulphuric acids, and most mineralogists have regarded it as a variety of Labradorite.

In the rock which he calls Euphotide, M. Delesse found in this material, the composition of Labradorite; containing about 50% of Silica and a specific gravity of 2.65.

But, according to Boulanger, the material regarded as Feldspar in the Euphotide of Orezza does not contain more than 43.6% of Silica. That of Mont Rosa, according to Sterry Hunt only contains 43.59%; and, moreover, it possesses a density of 3.365. Its composition and density resemble that of Anorthite or compact Zoïsite. We have reason, then, to distinguish among these rocks, those which enclose a feldspathic element, from those which possess amongst their essential elements, a substance resembling Epidote.

56. **Euphotide Labradorite.**—Compact, tenacious, usually white or grayish; and Smaragdite in large laminæ of a grass green color, exhibiting glistening fibres. This rock furnishes the *Corsica green* used by artists.

57. **Granitone.**—A crystalline assemblage of granitoid texture, having the appearance of a Diorite, and formed of Labradorite, usually of a greenish-gray color, and tablets or laminæ of gray Diallage, easily cleavable, of a copper-brown, or

olive-green color; often very fibrous; having a changing or chatoyant and metallic lustre.

Accidental minerals: *Olivine, Ouralite, brown or green Hornblende, Mica, Talc, Calc-spar, Epidote, Cubic Pyrites, Magnetic iron.*

58. **Variolite.**—This name has been given to this rock by reason of projections in the form of pustules left by the unequal alteration of the constituents. That of Durance is formed of a mass of grayish-green Feldspar of a slightly greasy lustre and a fracture of Petrosilex, which appears to be compact Euphotide containing these globules. These are gray on the exterior surface, but the interior is a beautiful green, sometimes violet. They contain 56% of Silica; 17.4% of Alumina; 7.79% of oxide of Iron; 8.74 of Lime; 3.41 of Magnesia; 3.72 Soda; 0.24 Potash; and lose 1.63% in the fire. Their density is about 2.9. In one variety found near Mount Genèvre, the globules have a greasy lustre and resemble Petrosilex. They are rounded fragments of a grayish-green color, in a deep green paste. Rammelsberg regards them as being made up of Oligoclase.

Accessory elements: *Diallage* (passing to Euphotide).

59. **Hyperite** (Syn. *Hypersthenite*).—Very rare; of granular texture, made up of grains of *Labradorite* and *Hypersthene*. The Labradorite is white, grayish, yellowish, bluish, or greenish. The rock at Hitteroe, called Norite by Scheerer is, doubtless, of this variety.

Hypersthene is of a blackish-brown, greenish, or bronze color; fibrous in texture; it sometimes reflects a copper-red color and is chatoyant upon the principal cleavage-face. The density of Hyperite is about 2.9.

Varieties: *Granular Hyperite; Compact Hyperite.*

Accidental minerals: *Epidote; Cubic Pyrites; Titanic Iron;* etc.

The name of Hyperite has been given to many of the Granitones of the Alps.

CHAPTER III.

AMPHIBOLIC ROCKS.

60. **Syenite.**—An aggregation of large crystals of Feldspar and Hornblende having a granitoid texture. Among the constituents, is Orthoclase which it contains in large quantity. This Feldspar presents itself in laminæ often of a tawny-red, or flesh color, sometimes violet.

Oligoclase is often found in grayish striated grains; *Hornblende* in the form of black or deep green prisms. The proportion of Silica varies from 60 to 61%. The Syenite of Ballon contains, according to Delesse, 19% of Orthoclase of a tawny-red color; 33% of white Andesinite; 19% Hornblende; 29% of Quartz; and a small quantity of Sphene, black Mica, Magnetite, etc. Its density is 2.7. That of Rennas, Sweden, according to the same author, is composed, principally, of reddish Orthoclase, enclosing Oligoclase of a greenish color; Hornblende of a greenish-black color; a little Oligiste; traces of the Carbonates; a little Quartz; Cubic Pyrites; and Epidote. Its density is 2.623; it has 78% of Silica.

Accessory elements: *Mica* with a bright lustre, often black; *Quartz* of a glassy aspect, often smoky; *Zircon; Sphene* in small yellow or brown crystals; *Epidote; Elæolite; Magnetite.*

In certain varieties, the grains are very fine and the large crystals of Feldspar render them porphyritic. The Syenites form considerable masses of rounded summits in Gneiss, Mica, Schists, and among the transition rocks. They pass into Syenitic granites by insensible gradations. Some Syenites contain a ferruginous Hornblende which readily decomposes to an ochrey clay.

Zircon Syenites.—In these rocks the Hornblende has disappeared almost entirely, and the Feldspar presents itself in that

beautiful variety of Orthoclase known as Microcline, in which the play of colors rivals that of Labradorite. *Zircon* is composed of Silica and Zirconium; it crystallizes in right prisms with a square base (Fig. 23). Its hardness is 7.5, and its density 4.67. It is infusible before the blow-pipe; insoluble in acids. It is usually of a red, brown, or yellowish-gray color.

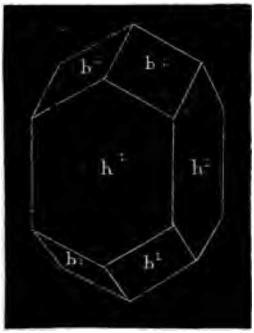

Fig. 23.

61. **Amphibolites.**—Rocks composed of *Hornblende*, sometimes *Actinolite.*

(1) Base of *Hornblende.* It is usually a variety of Diorite without Feldspar. In the Pyrenees it is not rare to find large blocks, made up almost entirely of Hornblende in prisms confusedly grouped, but having a very distinct cleavage. G. Bischof has described a rock of Hornblende in the form of a vein of coarse-grained Diorite of Weidenthal, of which the density is 2.947. Some varieties exhibit a schistose texture.

Accessory elements: *Garnet; Epidote; Feldspar.*

(2) With a base of *Actinolite.* Rocks composed of acicular prisms of Actinolite, parallel or grouped in tufts; usually the texture is schistose. Green Actinolite (Alps). Bluish Actinolite (New Caledonia). These rocks appear accidentally in the midst of schistose Diorites.

62. **Diorite.**—A granular aggregation of a blackish or green color more or less deep; mixed with whitish grains of *Hornblende* and *Oligoclase* in pretty nearly equal quantities. In the Diorites of the Pyrenees, Hornblende is generally dominant. The grains of Hornblende are prismatic, the fracture is laminated, brilliant black, or deep green; sometimes it is elongated and assembled in small tufts. Those of Oligoclase are striated white, yellowish-white or greenish. The density is about 2.9.

Accessory elements: *Quartz* in grayish grains; very abundant

in the granular varieties, where it attains the proportion of from 4 to 5%; *Albite*, rare; *Orthoclase* in the Diorites of the Hartz according to Kiebel; *Epidote*, very common, especially in the Diorites of the Pyrenees where it is either distributed throughout the mass, or in crystalline deposits upon the edges of the cavities. Durocher has found nearly 40% of Epidote in a Diorite of Saint-Beat, Haute-Garonne.

Accidental minerals: *Cubic Pyrites*, *Magnetite*, *Chlorite*, *Sphene*, *Magnetic Pyrites*, *Mica*. Diorites often break off in blocks more or less polyhedral, usually rounded, upon which one may see an argillaceous crust, yellow or brown, and rich in Magnesia and Hydrated oxide of Iron.

Varieties: *Ordinary* or *granitoid Diorite* has grains more or less coarse and uniform in size. The grains diminish in size as the rock vein becomes smaller. M. Delesse has, however, observed very different-sized grains in the same mass. *Porphyroidal Diorite* has fine grains with large crystals of Hornblende or Oligoclase.

Schistoide Diorite. Hornblende in laminæ with alternate layers of Oligoclase.

Micaceous Diorite of M. Delesse; a good deal of Mica; some Quartz; 48.9% of Silica.

Monzonite (Rock composed of Pyroxene according to Cordier; Hornblende according to M. de Lapparent). This variety passes to Syenite.

Norite of *Esmark*. Diorite containing little Hornblende and passing to Granite with Oligoclase. Diorites, after the manner of Granites, form a considerable mass among the crystalline rocks. Those of the Pyrenees pierce the nummulitic formation. Certain varieties of schistose texture appear subordinate to Mica Schists or to Gneiss.

63. **Corsite** (*Diorite orbiculaire*, *Diorite globaire*, *Granite de Corse*).—A granular assemblage of Anorthite, Hornblende and a small quantity of Quartz. The elements in this rock show a characteristic disposition. They are frequently disposed in

thin layers, slightly spherical, in which predominate alternately, Anorthite and Hornblende. In any cross-section may be perceived the resulting black and white bands of these minerals. The rock contains 48.05% of Silica, and 11.04% of Lime. Its density is 2.768. It contains 84% of Anorthite soluble in acids, and 16% of Hornblende. These results are due to M. Delesse.

64. **Aphanite**(*Dioritine Cordier*).—A compact mass having the aspect of a paste analogous to that of Petrosilex, but formed of Oligoclase and Hornblende in indistinct and intimately mixed particles. It is very tenacious; sometimes sonorous. Colors: greenish-gray and blackish. Fracture: conchoidal, often glittering. Density of the Aphanite of the Vosges, 2.968. Proportion of Silica, 46.83 (Delesse).

Accidental minerals: *Pyrites; Epidote.*

Varieties: *Massive Aphanite; Schistose Aphanite.*

Dioritic Porphyry. Paste of Aphanite with crystals of Oligoclase and Hornblende.

65. **Tonalite.**—A fine-grained rock, composed of striated snow-white Feldspar which has the exterior characteristics of Oligoclase, but which contains only 57% of Silica; Quartz in grayish grains; small quantities of blackish-green Hornblende; and brown Mica.

Accidental minerals: *Sphene, Magnetite, Pyrites, Corundum,* and *Orthite.*

CHAPTER IV.

EPIDOTE, GARNET, DISTHENE, etc.

66. **Cyanitfels.**—Rock formed of clear or deep blue disthene.

Accessory elements: *Garnet, Smaragdite, Silver Mica.*

Disthene is a silicate of alumina, and crystallizes in double elongated prisms, generally of a blue color. Hardness, between 5 and 6. Density, 3.69. Infusible and insoluble.

67. **Eclogite.** — (Syn. *Omphazitfels*). A granular assemblage, of a granitoid texture, of Smaragdite of a beautiful green color, and a variable quantity of Garnet of a bright red color.

Accessory elements: *Disthene* in azure blue fibres; *Epidote, Quartz,* and *Mica.*

Accidental minerals: *Magnetite, Pyrites, Rutile,* etc.

68. **Grenatite.**—Rock essentially formed of reddish-brown or yellowish garnet; granular or compact; showing no sharp crystals except on the sides of crevices.

Accessory elements: Acicular *Actinolite, Hornblende, Magnetite, Talc,* and often *Calc-Spar.*

Stratiform masses in crystalline schists. Often garnet appears in compact bands, parallel and undulating in the midst of calcareous rocks.

69. **Scapolite.**—Aggregate of fine grains or compact rock harder than feldspar. Density, 3.

Essential elements: *Scapolite.* Silicates of aluminum, calcium, and sodium, which crystallize in right prisms with a square base. Fusible before the blow-pipe; soluble in acids and about as hard as Feldspar.

Accidental minerals: *Pyrites, Graphite.*

This rock forms a vein in the strata of Oligiste in the Hartz Mountains.

70. **Epidotite.**—Rock of a green color, essentially formed of Epidote in fine grains or compact. It contains a little Quartz, and fuses before the blow-pipe to a brilliant black enamel. Epidote is a silicate of aluminum, calcium, and iron. Fusible, often, with intumescence; soluble in acids. Hardness, slightly inferior to quartz. Density, about 3.4. The color of Epidote in rocks varies from pistache to yellowish-green.

Accidental minerals: *Garnet*, *Calc-spar*, *Pyrites*. Epidote is found in chlorite schists.

CHAPTER V.

MICACEOUS ROCKS.

71. **Griesen.**—An assemblage of Quartz and Mica with a granular texture. It is a granite without Feldspar. The Mica is yellowish-gray or greenish, and has a brilliant lustre. The Quartz is crystalline and gray.

Accessory minerals: *Oxide of Tin*, in black grains, vitreous fracture, slightly resinous lustre; *Feldspar* (passing to Granite).

Accidental minerals: *Fluorine, Apatite, Topaz, Tourmaline Emerald, Copper Pyrites, Mispickel, etc.*

72. **Mica Schists.**—A crystalline, granular assemblage of Mica and Quartz of schistose texture. Mica forms, generally, one third or one half of the mass, but sometimes the quantity of Mica is so small as to merit only the name of Micaceous Quartzose Schist. In other cases, Quartz is nearly wanting. The proportion of Silica varies from 40.7 to 69.45. It attains 82.38% at Mont Rosa.

Mica presents itself in rocks in the condition of independent scales disposed in thin layers. Quartz, crystalline and granular, fills the space which separates these layers, which exist in parallel bands, plane, undulated, or folded in zig-zags. The more abundant the Mica, the more schistose the rock. The rock is easily split along these bands of Mica. Such a fracture is often wrinkled. It reflects light brilliantly and shows no Quartz. It is only in a fracture across the layers that one can see the true proportion of Mica.

When the Quartz is very abundant, the schistose character is only slightly apparent, and the Quartz forms nodules surrounded by the Mica. The Mica is usually one of the potash series, having two optical axes. It is genērally clear gray,

green, yellow, or white. Certain Mica schists have a black color, owing to a ferro-magnesian Mica of this color.

Damourite of a pearly lustre and containing water, sometimes replaces true Mica.

Accessory elements of the Mica schists: (1) *Graphite.* It replaces Mica more or less completely and gives the rock its characteristic lustre (*Graphite Mica schist*).

(2) *Calcite.* This replaces the Quartz in Calcareous Mica Schists (passage to Cipolins).

(3) *Garnet.* Sometimes as abundant as the essential elements, it forms rhombododecahedrons of red or brown grains. It seems to have crystallized after the Mica.

Mica Schists are associated with *Feldspar, Talc, Chlorite, Amphibole,* passing to Gneiss, to Talcose, Chloritic, or Hornblende Schists. Red oxide of Iron establishes transition to Itabirite.

Accidental minerals are extremely numerous. We will cite only: *Tourmaline, Andalusite, Staurotide, Emerald, Apatite,* and occasionally *Cubic Pyrites, Mispickel.*

Mica Schists cover or envelop the Gneisses. They form sometimes high mountains intersected by great crevasses. The alteration consists chiefly in the per-oxidation of the Iron contained in the Mica. When complete, it results in an ochrey clay, sandy and micaceous.

Micaceous Sand.—Mica in Scales mixed with Quartz, in grains.

73. **Minette** (Syn. *Fraidronite*).—

Essential elements: a paste of Orthoclase, a nearly equal quantity of Ferro-magnesian mica, and, occasionally, Hornblende. It contains Silica, varying from 50 to 65%. M. Delesse, who made a study of this mineral, considers it Eurite with an excess of Mica; richer in Magnesium and Iron than Porphyry. The rock is black, sometimes brown, in consequence of alteration, and often brilliant. That of Alsace has a density of 2.65. Easily fusible before the blow-pipe. The paste is deep gray or reddish-brown, sometimes porous. It often contains laminæ of red-

dish Orthoclase. Sometimes distinct crystals of Orthoclase give to the rock a porphyritic appearance. The Mica is of a blackish-brown. The two axes diverge, at most, 5°. Hornblende of a grayish-green or deep green color; it contains about 10% of water. It is altered.

Accessory elements: *Chlorite*, *Oxide of Iron*, *Carbonate of Iron*.

Accidental elements: *Calcite*, *Quartz* rare, *Epidote*, etc.

When the Orthoclase appears in globules, the rock becomes globuliferous. It separates naturally, and the Minette assumes a schistoid character and sometimes divides into parallelopipedons. It forms veins in Granites and in the Syenites of the Vosges. It is found in Saxony, called *Trap glimmer* by Naumann. The Minette of central France was called Fraidronite by Dumas.

74. **Leptynolite.**—This name, Cordier has given to rock which bears the same relation to Minette as Gneiss bears to Granite. It is of a gray color, more or less blackish; schistose or tabular; and is formed of Mica and Feldspar. It is generally speckled with a black material externally, but is white in stripes and is regarded as a macle imperfectly developed. It belongs with the crystalline schists and is classed by German lithologists among the older argillaceous schists.

75. **Kersanton.**—Grayish or greenish-gray rock, composed of a green or gray paste of Oligoclase, with a much smaller quantity of Mica of a copper-brown or blackish color, containing Manganese and Iron; and, finally, of Carbonate of Iron mixed with Calcite, visible under a slight magnifying power. The Calcite often forms nodules which are enveloped by the Mica.

Oligoclase is sometimes found in separate distinct crystals, white or greenish-white, giving the rock a granitoide texture; it has generally been altered, which renders it easy to crush or cut. Kersanton is discolored when treated with hot hydrochloric acid.

It bears the chisel of the sculptor, as may be seen in the monuments of Brittany. M. Delesse has made a study of it.

He shows that the rock does not contain Amphibole. It is, according to this same lithologist, sometimes found in an analogous rock of Visembach. This rock, of a blackish-green color contains more than 70% of Oligoclase, generally in the state of paste, and less than 30% of Mica in microscopic particles mixed in the paste. It effervesces in acids and contains as accidental minerals: *Cubical Pyrites; Magnetic Pyrites; Chalco-Pyrites;* and *Amygdaloidal* forms of *Quartz*, *Chlorite*, *Epidote* and *Calc-Spar*.

M. Delesse regards these characters as sufficiently different from those of Kersanton, to warrant the name of Kersantite.

CHAPTER VI.

CHLORITIC ROCKS.

76. **Chloritic Schist.**—Aggregate of a more or less greenish color and schistose texture of chlorite, generally mixed with Quartz in grains. Generally, notwithstanding their schistose character, these rocks are not easily separated into laminæ.

Accessory minerals: *Feldspar*, *Actinolite*, *Mica*, and *Talc*.

Accidental minerals: *Carbonate of Magnesia: Magnetic Iron ore* in octahedrons; *Garnet* in rhombododecahedrons, often of a hyacinth-red color; *Diopside; Epidote; Sphene; Actinolite; Tourmaline; Corundum; Iron and Copper pyrites; Calcite* in mass; *Quartzite* in layers; *Serpentine.* The Chlorite schists alternate with the other crystalline schists—Talcose schist, Mica schist, Hornblende schist, etc. Allied to these rocks is Topfstein. Associated with the Chlorite schists also are Satin Phyllades of Canada, which contain numerous crystals of Pyrophyllite which is doubtless an essential element.

77. **Glauconyte.**—This name is given to a Silicate of Iron with Potassic hydrate. These rocks differ chemically from the Chlorites in containing much more Silica (40 to 54%); and, generally, much less Alumina (2 to 7%). It is known only in grains mixed with calcite or sand which give it an oölitic appearance. Examples: Glauconyte or Chloritic chalk of the Paris basin; Glauconyte from Silurian beds in Russia; Glauconyte Sandstone, generally green or brown when the Ferrous oxide of the Glauconyte passes to the condition of a hydrate.

Grains of Glauconyte often present themselves in the form of shells fitting one on the other. They are found at St. Petersburg, in the Devonian system; they characterize the green Sandstone of the Paris basin and the Tertiary formation at Vienna and abound in the Swiss Molasse.

78. **Chamoisite**—Rock of a bluish-black or greenish-gray color with an oölitic or compact texture and an earthy aspect; owing these characteristics to its essential elements.

The mineral Chamoisite contains 50 to 60% of Ferrous oxide; 12 to 14% of Silica; 7% of Alumina; and 17.4% of water. Specific gravity is above 3. It yields black magnetic scoriæ before the blow-pipe, and deposits gelatinous Silica in hydrochloric acid. It is often mixed with a large amount of Calcite. This mineral forms veins in the Swiss Jura.

An analogous Berthierite, a mixture of Ferric carbonate and oölitic Limonite, forms the Iron ore of Hayanges.

Calamine.—Hydrosilicate of Zinc in nodules, in concretionary masses, earthy, white, sometimes blue or green. The crystals are right prisms with rhombic bases. They are pyro-electric. It is soluble in acids, forming a jelly. Yields water in the closed tube and fuses on the edges before the blow-pipe.

The powder heated with nitrate of Cobalt gives a green reaction.

CHAPTER VII.

PERIDOTE, TALC, AND OTHER MAGNESIAN SILICATES.

79. **Lherzolite.**—A granular mass, composed of Peridote in olive-green grains, infusible before the blow-pipe, forming a jelly in acids; of Enstatite in grayish-brown grains, difficult to fuse and insoluble; of chromiferous Diopside in emerald-green grains, fusible to a green bead, giving chromium reaction with salt of Phosphorus; finally, of black grains of Pleonaste, containing 8% of Chromium and called Picotite. (This analysis is due M. Damour). In the mass, the rock is green or blackish-green, with a density of 3.28.

80. **Dunite.**—A crystalline aggregation of grains of Peridot of a grayish or yellowish-green color with a greasy or vitreous lustre, in the fracture. Density, 3.3. Hardness, 5.5. Infusible. Dissolves in hydrochloric acid.

81. **Serpentine** (Syn. Ophite).—Rock formed essentially of the mineral of the same name, and which was regarded by the ancients as the best remedy for the bites of poisonous serpents. It is a Magnesium silicate and hydrate containing 40 to 44% of Silica; 33 to 43% of Magnesia; 10 to 15% of water; 1 to 10 of Ferrous and Ferric oxides; and from 1 to 6% of Alumina, and, rarely, a little Chromium or Nickel oxide. It is compact, fine-grained or foliated, slightly laminated, but with the laminæ inseparable; or sometimes fibrous with the fibres forming a kind of Asbestos called Chrysotile. It is separable into large blocks or masses, whose surfaces present a characteristic lustre like varnish.

Often these masses are separated by layers of Mica, Chlorite and Calcite of fibrous texture. It is soft to the touch, sometimes rough. Its hardness, from 3 to 5; density 2.63.

Precious Serpentine is a translucent variety with a color varying from a sulphur-yellow to an asparagus-green.

Common Serpentine, more opaque, exhibits colors varying from clear green to dark green in the same mass, so that, when polished, it resembles the skin of a snake. It is sometimes red, brown, or even black. The lustre is dull or resinous, with a fracture generally laminated. In the closed tube, it yields water and blackens. Its fusibility is about that of Talc. It is decomposed by hydrochloric or sulphuric acids, depositing Silica.

Accessory minerals: *Diallage*.

Accidental minerals: *Garnet*.

Serpentine has generally a schistose texture, found in crystalline schists or sometimes in veins. It forms dikes, breaking through sedimentary rocks of different ages, and is found with the Gabbros, with Eclogite and Diallage, or Hornblende rocks.

It contains considerable masses of chrome Iron or Magnetite.

It resists atmospheric agencies and yields nothing to vegetation; in New Caledonia and among the Alps, the inhabitants apply the name Dead Mountains to hills composed of these masses. The prolonged action of the water and carbonic acid of the atmosphere finally produce carbonate of Magnesia, Opals, fine Siliceous deposits, and sometimes sulphate of Magnesia, when the original rock contains Pyrites. A serpentine-like mass in little laminæ, which is regarded as arising from the decomposition of crystals of Peridot associated with Feldspar, is called by the Germans *Forellenstein*. These two elements can be distinguished only when they are of considerable size. This rock is quite abundant at Volpersdorf.

82. **Meerschaum.**—Magnesium hydro-silicate. Dull white, or faint rose color; hardness 2.5; density 1.2, in the best specimens. It releases water in the open tube, fuses with difficulty but is decomposed by hydrochloric acid, the solution giving Magnesium reaction.

83. **Talcose Schists.**—An aggregate of laminæ or scales

of Talc, with distinct schistose texture, of a clear yellow, greenish, or emerald-green color, rarely red; soft and greasy to the touch.

Accessory elements: *Quartz* in elongated masses; *Feldspar; Chlorite; Mica.* In certain varieties, the Feldspar forms nodules, producing contortions in the laminæ.

Accidental minerals: *Garnet, Tourmaline, Staurotide, Disthene, Oxide of Iron, Pyrites, Graphite, Dolomite, Corundum,* etc., in alternate layers with the other crystalline Schists.

Topfstein *(Pierre à pot, pierre ollaire)*:

(1) A Talcose variety formed of compact and impure Steatite;

(2) Chloritic talcose variety, the most common.

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CHAPTER VIII.

ARGILLACEOUS SCHISTS AND SLATES.

84. Slates (Phyllades).—This rock is characterized by the property to which lithologists give the name cleavage; not applied, as in the case of minerals, to a body of definite composition. It is exhibited in rocks of different character and in constant direction, but generally oblique to the plane of stratification.

Generally, this property in the slates is accompanied by a cohesion quite exceptional, which renders the separate laminæ of sufficient strength to be employed for roof coverings. Slates generally present the following characteristics: their cleavage-surface is always flat, sometimes scaly; they present a lustre frequently like that of satin or silk. Those varieties which contain carbonaceous matter present a pearly lustre and may be decolorized when raised to a temperature sufficient to burn their carbon. The powder is soft to the touch. They fuse before the blow-pipe and sometimes exfoliate.

The lower strata which touch the crystalline schists and sometimes alternate with them, resemble the micaceous, or talcose schists by their glittering or satin lustre and by their low degree of hardness. The upper strata pass insensibly into argillaceous schists. They are harder than the preceding, but easily scratched by a steel point.

Chemically they contain 60% of Silica; 15 to 20% of Alumina; the remainder being a variable proportion of Magnesia, Potassa, Calcium, Sodium, and water. The water is not always present, but sometimes it reaches 2 or 3%.

Hydrochloric acid dissolves from 12 to 27%; Sulphuric acid from 25 to 50%. Specific gravity, from 2.64 to 2.95.

Slates appear to be composed of:

(1) Particles extremely fine and not widely different from

Talc in their composition or physical properties, and are allied, the one to the Micas, and the other to the Clinoclores.

(2) Feldspar and Quartz forming a paste of grains. Often also of oxides of Iron and Anthracite in minute particles. The shining or micaceous slates are doubtless richer in materials of the first group.

List has found Sericite as an essential element in slaty schist of Taunus. Pyrophyllite, nearly compact, forms true strata in the United States (Deep River). Often, different varieties are intermingled. In the slates of Ottrez, an amorphous material allied to Pyrophyllite forms a matrix enclosing Quartz and Mica.

The colors of slates are various; green, violet, blue, red, gray, yellow, black and their mixtures. Black is due to carbonaceous matter. Some other colors are produced by the oxides of Iron. Green is due to chlorite or some organic matter.

Accessory elements: *Graphite, Amphibole, Talc, Chlorite, Magnetite, Macle.* This latter produces schists of a deep black color, composed of slates whose faces of fracture are rendered rough by innumerable crystals of *Macle* disseminated through them; *Staurotides* forming schists (crystals badly defined), *Quartz sand, Crystalline Quartz* in veins.

Nodular-Slates. In some kinds of slates are Pyrites which seem to have replaced fossils; others which contain Mica; and others again, which lithologists consider as Fahlunite or Macle (Glandular schists). In certain varieties the Macle presents itself in blackish spots (Spotted schists). It is difficult to tell in many cases, whether to class the rocks among the slates or the Mica schists.

Porphyroidal Slates. Some kinds take this name from the numerous crystals of Feldspar which they contain, the deposit of which was evidently subsequent to the formation of the rock.

Slates envelop Mica schists; most of them belong to the transition rocks; some occur in the cretaceous formation of the Caucasus and the Eocene of Switzerland. At the other extremity

of the series of stratified rocks, they alternate with Talc and Talcose schist, in the Alps at Salsburg and in Silesia; with sand, clays, and limestones in Bohemia, England, and the Hartz.

They constitute great folded masses, sometimes appearing in abrupt and sterile cliffs.

In some varieties, in addition to the plane of easy cleavage, another is found parallel to the plane of stratification, and the rock breaks easily into small crayon-like prisms.

85. **Novaculite** (Whetstone).—A slate impregnated with Silica, which renders it harder, and gives it a slightly conchoidal fracture, and makes it less fissile. It passes to ordinary slate.

86. **Clay-slate** (Schiste Argileux).—Rocks of an eminently slaty texture, composed of clay, often mixed with Mica in scales and generally with grains of Quartz. They are Silicates of Alumina containing 4 to 5% of water. Frequently the schists of the transition formations exhibit this particular fissility which is called cleavage in the slates; they are also very compact, and their surface-fracture is very smooth.

The carboniferous clay slates, so rich in graptolites of the upper Silurian formation, are examples of these rocks. The slates of the higher formations have a larger grain; they are more friable and their stratification is more apparent. They are sometimes distinguished from the preceding by the term *slate clays* (argiles schisteuses).

Sometimes the scales of Mica appear on their fracture-surface, giving them a lustre. They are easily fusible before the blowpipe. They often contain carbonaceous matter and Bitumen, Pyrites, Blende, Galena, Nodules of Spathic Iron, impressions of fish scales filled with sulphide of copper.

87. **Ampelite** is a clay schist, or slate; soft, dull, black, impregnated with Anthracite and Pyrites, the sulphur of which oxidizes, forming a sulphate with the Iron or with the Alumina. The sulphates resulting from this decomposition, are used as fertilizers. When the carbon is in large proportions, Ampelite is used for black crayons.

88. **Argillite** (Syn. Clay stone).— This rock bears the same relation to the Clay slates as Novaculite does to the preceding series. These compact, solid masses are formed of Alumina combined with an excess of Silica; they have an Argillaceous odor, but fuse with difficulty. They adhere slightly to the tongue. They have flat or conchoidal fracture and sometimes a Jaspery aspect. They form massive beds which tend to divide into little fragments.

It seems proper to include here, certain siliceous schists, too hard to be scratched by a steel point, but fusible, although with difficulty; for example, a schist of Osterode in the Hartz which contains 61.24% of Silica; 18.75 Alumina; 11.70 Ferric oxide; the remainder being Magnesia, Potash, and Soda. Argillite exhibits all degrees of transition to the siliceous schists, and is found in beds in transition, and in carboniferous formations.

89. **Thermantides** (Porcellanites).—Rocks resembling enamels, more or less vitreous; of a lavender, pearl-gray, yellowish, brownish, and sometimes of many other colors arranged in parallel bands. They are compact, sometimes slightly schistose, opaque or slightly translucent and fusible to clear globules. They result from the vitrification of clay in contact with Basalts, or from coal deposits burned.

90. **Kaolin** (Porcelain earth). — Silica 47.05; Alumina 39.21; Water 13.74. Density varies from 2.4 to 2.6; hardness, 1 to 2.5. The lustre is pearly or earthy; it sticks to the tongue; it is generally found in large masses; white, reddish, and more or less mixed with oxide of Iron, Quartz, or Mica. Infusible and not attacked by boiling Sulphuric acid. It results from the decomposition of Aluminic silicates, principally of Feldspar, Granite, Gneiss, Pegmatite, Porphyry, or Trachyte.

It serves sometimes as the cement of sandstones and conglomerates.

91. **Plastic Clay** (*Argile Plastique*). — This possesses more Silica than Kaolin and forms a paste with water, which is easily moulded and preserves the form impressed upon it. In the dry

state, it is more or less earthy, friable, dull, soft, unctuous. It contains veins of a red, yellow, greenish, bluish, or blackish color. Density, 2.44. It is infusible. Is attacked by sulphuric acid, especially after calcination.

The purest varieties are used in porcelain manufactories. Others, having a larger amount of Silica, are used to make Fayence. When it is colored by carbonaceous matter, it is decolorized by fire. The reds, yellows, and greens become red by baking.

Pottery earth.—More friable and fusible. Often a mixture also of some hundredths of Quartz sand or Lime. It contains also white Pyrites, Gypsum, Lignite, and Aluminous limestone, called Septaria. When the proportion of Lime is more than 20%, the mixture is called Marl.

92. In certain varieties, the Alumina is, in part, replaced by red oxide of Iron to the extent of from 15 to 20 %. The very ferruginous rocks, called *boles*, are greasy to the touch, and break into fragments when treated with water. They are in part attacked by hydrochloric acid and are fusible. They are found in the Melaphyres and Basalts.

93. **Lithomarge.**— Compact clay ; greasy to the touch; fracture often conchoidal; colors, often in bands; slightly harder than gypsum ; density 2.5. to 2.6. Chemically it differs slightly from Kaolin. It is found in veins, in contact with Porphyry and Serpentines.

94. **Fuller's Earth.**—Contains more than twice as much water as the preceding. Sticks to the tongue, and is valuable for its power of absorbing oil or grease.

It is fusible before the blow-pipe. Does not form paste in water, but is attacked by acids and alkalies. It is generally grayish or greenish, but sometimes spotted. In a fresh fracture it has quite a lustre.

95. **Magnesian Clay.**—This is a mixture of ordinary Clay with Magnesite. Absorbs water very readily. It is found in the tertiary beds near Paris. Forms a jelly in hydrochloric acid.

96. **Loam** (*Limo*).—Clay mixed with very fine sand; sticks to the tongue; has a brown or yellow color owing to the oxide of Iron. It generally contains sulphates and phosphates of the alkalies, and some organic matter. It forms the fertile soils.

97. **Vegetable Mold** (*Terrau*).—A brownish or greenish or blackish loam containing 7% of organic matter, of a remarkable fertility. It covers eighty millions of hectares between the Carpathian and Ural mountains. The microscope reveals diatoms in this earth.

CHAPTER IX.

SILICEOUS ROCKS.

SILICA exists in two isomeric conditions; in the first, it is insoluble in acids and alkaline solutions. It is always anhydrous; it has a crystalline structure and a density of 2.6. It is this which forms quartz crystals, agates, and jaspers. The second variety contains water; has a density of 2.2 or more. It is exhibited in the Opal. All varieties of Silica are attacked by hydrofluoric acid.

Fig. 24.

Rock Crystal.—SiO_2. Silicon, 46.67; Oxygen, 53.33. Forms a regular hexagonal prism, terminated by a hexagonal pyramid (Fig. 24); or the pyramid only, may be exhibited (Fig. 25).

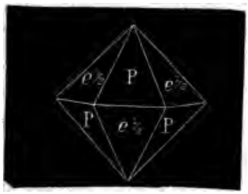


Fig. 25.

Quartz has a hardness of 7; it scratches Feldspar, and is marked by Topaz. When powdered, it may be fused with potash. When pure, it is colorless and limpid, but is often black, through the presence of carbon (*crystal fumée*); violet from Manganese (*Amethyst*); red or yellow from oxide of Iron; and rose or greenish from other matters. It often has a greasy aspect; and always a vitreous fracture.

98. **Massive Quartz.**—Masses more or less fissured, of a milk-white or grayish-white color, irregular fracture, greasy lustre, traversing the sedimentary and lower transition rocks.

99. **Tourmaline Quartz.** — Granular or schistose aggregate of grayish Quartz grains, and black or deep green grains of Tourmaline, associated with the Granites or Pegmatites.

100. **Topaz Rock** (*Topaz fels*).— A Breccia-like aggregate of pale yellow Topaz, Hyalin, Quartz, and black Tourmaline.

Accidental minerals: *Apatite, Cassiterite.*

101. **Quartzites.**—Accessory elements: *Mica, Talc, Feldspar.* Varieties: *Granular Quartzite,* gray Quartz grains aggregated without cement. Sometimes the grains are very small (compact Quartzite). These rocks assume a porphyroidal aspect when they contain distinct crystals of Feldspar.

Elastic Quartzite.—The grains are arranged in rows or files separated by layers of Mica scales. The rock has a loose texture and considerable elasticity.

Schistose Quartzite.—The schistose character arises from laminæ of Talc or Mica distributed in parallel layers, along which the rock is easily divided.

The Quartzites are found principally in the midst of Mica Schists. They form dome-like mountains, rising from the débris of rocks which have given way earlier to the atmospheric influences.

102. **Agates.**—Apparently a mixture of crystalline Quartz, and amorphous Quartz with a conchoidal fracture. The lustre is something like that of wax, bright on polished surfaces. The colors are bright, often varied in the same fragment, and frequently in parallel bands or concentric zones.

103. **Flint.**— It has a conchoidal fracture, breaking into sharp-edged fragments, translucent at the edges. Acted upon slightly by Hydrate of Potash. It contains 1% of water and 1% of Lime, Alumina, and oxide of Iron. Under friction, it gives a peculiar and slightly bituminous odor. Flints are widely distributed in irregular layers, in the secondary formation, particularly the cretaceous. Color: variable; generally gray to black.

Hornstone (*Silex Corné*).—Flint with a flat conchoidal fracture; gray to brown; often schistose; *Burrstone* (*Meulière*). Flint of a greenish-white or yellowish color with a resinous or earthy lustre. It is full of minute cavities, sometimes full of clay.

104. **Jasper.**—Crystalline quartz in compact masses, opaque, dull, and colored yellow, red, green, black, bluish, pearl-gray by different matters. Often the colors alternate in parallel bands. It is hard and capable of receiving a beautiful polish. It is found in small masses in the vicinity of Serpentines and Melaphyres.

105. **Quartz Schists** (*Phtanites*).—A kind of black Jasper composed of Quartz containing clay and Ferric carbonate. The colors are black, brown and greenish. Proportion of Silica 75%, or less, to 96%.

It often presents itself in very thin layers. It abounds in the transition earths (*Bohemia*); and elsewhere in the carboniferous (*Belgium*).

106. **Resinites.**—Amorphous Silica of a gum-like structure, soluble in hydrofluoric acid and boiling alkaline solutions; it may be fused with potash. Generally transparent; sometimes opaque; conchoidal fracture; lustre resinous. Iridescent lustre in the opals of Hungary and Mexico. Colors: bright and varied. Hardness, 5 to 6. Density, 2.2. Often contains water in great quantity; sometimes very little.

A variety, found at Bry-sur-Marne, contains much water, but loses it when exposed to the air. It recovers this water in a humid atmosphere.

Opal is found only accidentally in the rocks. It occurs in veins in the Trachytes, and in small nodules in the Sedimentary rocks. (Ménilite; opal with a dull fracture, splintery, grayish or bluish-gray color).

Geyserite.—*Siliceous Sinter.* More or less compact; often friable, forming stalactites and incrustations, disposed in zones, etc. Color varying from snow-white to grayish-white, bluish, reddish; often full of cavities.

107. **Gaise.**—This name is given to a hydrated siliceous earth.

108. **Infusioral Earth** (*Silice Farineuse*).—An impalpable Siliceous powder, of which each grain is the skeleton or carapace of some infusoria.

Tripoli (*Polishing slate*).—An eminently schistose rock, of earthy appearance, the fine scales of which result from the juxtaposition of grains of the preceding variety.

109. **Gritstone** (*Grés*).— Rock composed of irregular grains, cemented by the same or a foreign material. The name is applied to either fine grains of Quartz, Feldspar, or laminæ of Mica, cemented either by silica or lime or clay, or a mixture of them.

Siliceous Sandstone (*Grès Quartzeux*).— Composed of gray or limpid grains of Quartz. The surface is irregular. Crystalline facets are rare. It exhibits a splintery fracture, more or less conchoidal. Color: grayish-white or colored by foreign matter. The cement of Silica gives it great coherence, considerable hardness, and quite a shining lustre.

In the *Calciferous Sandstone* the cement is of lime, more or less mixed with Mica or Glauconite. It is friable. Hydrochloric acid dissolves the cement with effervescence and releases the sand. A Schistose sandstone is found in the variegated sandstones of the Lias formation.

Argillaceous sandstone.— The cement is clay with oxide of Iron. *Brown sandstone* has larger grains with an argillo-ferruginous cement. *Quader sandstone* is made up of cubical blocks cemented together. *Vosges sandstone* is composed of translucent grains of Quartz, of considerable size; bright surface, mixed with dull white grains of Feldspar, and cemented by a paste of a red, violet, or ochre-yellow color of ferruginous character. Ferruginous sandstones are found in the old or the new red sandstone formations. *Glauconite sandstone* contains grains of Glauconite of a green or brown color. It is found in the Devonian, Cretaceous, and Tertiary systems. Some sandstones contain a certain amount of bitumen (*Bituminous sandstones*). Some others contain débris of slates (slaty *sandstone*).

110. **Arkose.**—Sandstone composed of grains of Quartz and Feldspar. M. De Bonnard applied the name to a portion of the lower Lias group which consists of the débris of granitic

rocks; Feldspar; Mica in non-elastic laminæ and a much greater quantity of granular Quartz; the whole united by a cement of calcite, more or less crystalline; often also of a chalcedonic paste resembling hornstone, or finally of a mixture of Quartz and Baryta, or Fluor-spar. The rock is then a sandstone or a conglomerate, dependent upon the size of the fragments. It is nearly always a sandstone, but sometimes resembles granitoid porphyry.

Accessory minerals: *Fluor-spar*, *Barytite*, *Quartz*, *Galena*, *Pyrites*.

111. **Micaceous Sandstone** (*Grès Psammite*).—An assemblage of grains of Hyalin Quartz, scales of Mica, and grains of Feldspar, joined by an argillaceous cement, often very schistose. Colors, red or blue (*Buntersandstein*).

Cordier applied the name of *Metaxite* to Arkose that contained kaolinized Feldspar.

112. **Macigno Sandstone.**—A sandstone composed of grains of Quartz and Feldspar, with scales of Mica distributed in parallel planes, giving it a schistoid character. The siliceous matter which serves as a cement, renders it solid enough to merit the name of *Pietra forte*. It is the characteristic rock of the Eocene of Italy.

113. **Molasse Sandstone.**—A Sandstone of the Alps made up of Quartz, Feldspar, some Calcite, Mica and Glauconite. Its calcareous or marly cement gives it the character expressed by its name.

From the above may be seen how numerous are the Sandstones. Only the most characteristic forms have been here described. They are found in all regions of the earth. They form mountains of considerable size, rounded into domes, and divided by immense crevasses.

114. **Sand** (*Sable*).—This name is given to loose grains of different materials, more particularly Quartz. It is the principal element of the moving soil or dunes of the desert. It is the chief material of alluvial deposits. It is a necessary element of

arable soil, as it tends to render friable those materials, which, without it, would be too compact. It is often penetrated or incrusted with oxide of Iron (*Ferruginous Sand*). It sometimes contains fragments of Garnet crystals, titanic Iron, or oxide of Tin, etc. When it contains pebbles of Quartz, it is called gravel.

115. **Quartz Breccia** (*Brèche de Quartz*). — Quartz in angular fragments, united by a siliceous cement often ferruginous. The silurian formation presents the greatest number of examples, but it occurs in the carboniferous.

116. **Jasper Breccia** (*Brèche de Jaspe*). — Jasper in angular fragments united by a siliceous cement.

117. **Pudding Stone** (*Poudingue*).—Conglomerate of Quartz pebbles or rounded fragments of Flint united by a siliceous cement. *Quartziferous P.* with pebbles of Quartz *in a crystalline mass. Siliceous P.* Pebbles of Flint.

The new red sandstone in Saxony exhibits two kinds of rock. The conglomerate consists of blocks distributed through a cement of fine particles. The fragments differ widely from each other; being fragments of Granite, Gneiss, Mica schist, Porphyry, and Clay slates. The rock passes to a sandstone in which the Quartz predominates. Many conglomerates of the Alps are also polygenic; among them are:

118. **Gray Wacké.**—This is abundant on the borders of the Rhine. The cement is smoky gray, reddish, or brownish, and appears to be an argillaceous schist, impregnated with Silica. It binds together particles of Quartz, Feldspar, and Clay slate, or Phtanite and Siliceous schist. Scales of Mica often render it schistose.

119. **Anagenites.**—Cordier applies this name to sandstones in which the element Clay slate predominates; *Traumates* to those in which argillaceous slate dominates.

120. **Nagelfiue** (*Nagelfluhe*).—This rock forms the Rigi; it is formed of débris of Jurassic limestone, clay or siliceous schists, Quartz, and a siliceous and calcareous cement, not very

abundant. The pebbles or grains are rounded and appear on the surface like pin-heads; hence the name.

121. **Psephyte,** a conglomerate of Porphyry more or less altered, of Granite, Schistose rocks, cemented by a clayey material which arises from the decomposition of the Feldspar. This rock is found in deposits alternating with layers of Melaphyres, at the base of the Permian and in the Carboniferous systems. It generally contains rounded pebbles of Quartz and fragments of other rocks. Conglomerates of Melaphyres are also found. They sometimes exhibit a schistose character passing to Gray Wacke.

CHAPTER X.

ALKALINE ROCKS.

122. **Natron.** Carbonate of Soda ($Na\ Co_3 + 10\ H_2O$). Form: Oblique prism (Fig. 26). Density, 1.423. Colorless when pure; vitreous lustre; generally dull. It effervesces in acids, is soluble in water: colors the flame yellow and yields water in the closed tube.

Fig. 26.

123. **Trona.**—Also a carbonate of soda with same characters as preceding.

124. **Borax** *(Tinkal)*.—Sodic borate. Forms: nearly identical with those of Pyroxene. Colorless when pure; soluble in water and fuses to a transparent globule, and, if mixed with Fluorspar and Potassic sulphate, colors the flame green. Found native in Thibet and California.

125. **Nitre.**—*Saltpetre.* Potassic nitrate ($K\ NO_3$). Form: double hexagonal pyramid derived from a right prism with a rhombic base, whose angle is 118° 50′. Hardness, 2; density, 2.94. Colorless; vitreous lustre; burns violently on charcoal. Soluble in water.

126. **Nitratine.**—Sodic nitrate. ($Na\ NO_3$). Cleaves in rhombohedrons. Has a density of 2.2, and colors the flame yellow. It is found in Chili.

127. **Rock Salt** (*Sel gemme. Stein salz*).—Sodic chloride ($Na\ Cl$). Form: cube and cubo-octahedron. Hardness, 2; density, 2.2. to 2.3. Colors: flame-yellow; fuses; soluble in four parts of water. It gives with nitrate of Silver a white precipitate, which may be redissolved by an excess of Ammonia. It is found in masses with a cubical cleavage. It is colorless, blue or green, from salts of copper; a brick red by oxide of

Iron, orange red through infusoria. It is often distributed through clay or marl deposits.

It is found in the Silurian rocks in Ohio, Virginia, Pennsylvania, and New York. Also in the lower Triassic of Tyrol, the Permian of Mansfeld and in the Muschelkalk of Wurtemberg. It forms extensive deposits in the colored marls of England and Germany; in the same formations of Switzerland, France, and in the Jura. It is found among the ejected matter of volcanoes, and in extended masses whose geological position is not known, in Asia and Africa. It is the salt of the ocean and the salt lakes.

128. **Carnallite.**—Potassium chloride and Magnesium hydrate ($KCl+(MgCl)_2+12H_2O$). Colorless when pure. Sometimes mixed with Ferric oxide and presents itself in granular masses. It is soluble in water. Yields water in the closed tube.

129. **Cryolite.**—Fluorides of Sodium and Aluminum. Hardness 2.5 to 3. Density 2.96. Rarely exhibiting crystals; found generally in milk-white masses, colored sometimes yellowish by carbonate of Iron. It is easily fusible, colors the flame yellow, and is colored blue by nitrate of Cobalt. It is soluble in nitro-hydrochloric acid and is precipitated by sulph-hydrate of ammonia. Insoluble in Ammonia.

Sulphuric acid disengages hydrofluoric acid, which may be detected by its action on glass.

CHAPTER XI.

ROCKS OF THE ALKALINE EARTHS.

130. **Stassfurtite.**—A granular aggregate of Magnesium borate, Magnesium chloride, and a small quantity of sulphuric acid. Found in nodules in Rock salt of Stassfurt. Soluble in hydrochloric acid.

131. **Fluorspar** (*Fluorine. Flussath*). — Calcic Fluoride ($Ca\ Fl_2$).

Crystal; form: the cube modified upon its angles or its edges. Form of cleavage, regular octahedron. Hardness, 4. Density, 3.18. Colors: varied and bright; sometimes colorless and transparent. Fuses with difficulty. Treated with sulphuric acid, it corrodes glass. Exhibits a bluish fluorescence when heated in a closed tube. It exhibits itself in scattered veins in granitic rocks and quartziferous porphyries.

132. **Calcite** (*Calc-spar. Iceland spar. Calcaire. Kalkstein*).—

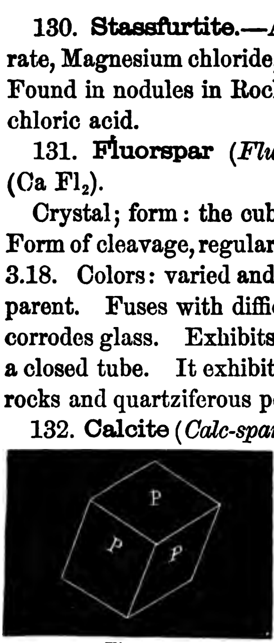


Fig. 27.

Calcium carbonate. The rhombohedral forms have three equal cleavages forming an obtuse angle 105° 5′.

Dominant forms: sometimes obtuse rhombohedrons, sometimes rhombohedral needles, or hexagonal prisms, scalenohedrons and hexagonal pyramids. Density, 2.72. Hardness, 3; scratched with a knife or even a pin. Heated, it becomes caustic lime and shines with a bright light. It effervesces in acids, and colors the flame red. When it is dissolved by an acid, a residue of sand often appears in the liquid. Some varieties have a geological importance.

Crystalline Limestone.—Aggregation of grains; often formed of many small, grouped crystals. Among these are distinguished: *Laminated limestone* formed of grains, so large, that the fracture

often exhibits cleavage-facets (marble of the Pyrenees). It forms masses subordinated to the Mica schists.

Granular Limestone.—Of smaller grains which resemble loaf sugar. The marble of Pentelicus is of this variety. The marbles of Venetian columns, those of Luni and Carrara are also examples. Often these marbles contain other matters, as *Mica* (Cipollino); *Talc* giving the rock a greasy lustre and sometimes a peculiar brecciated appearance *(false breccia)*; *Serpentine*, whose various tints produce rare effects *(Verde antique)*; Crystalline grains of *Garnet*, *Idocrase*, *Pyroxene*, *Sapphire*, *Apatite*, *Albite*, *Spinelle*, etc., are also found, giving sometimes a porphyroidal aspect. They sometimes occur in the Jurassic formation where geologists regard them as limestones metamorphosed by neighboring eruptive rocks.

Sedimentary crystalline Limestones.—In small masses in the midst of sedimentary deposits. They consist of a granular Calcite mixed with crystals of Quartz.

Manganiferous Limestones.—Containing Iron and some Manganese. Turn brown when heated.

Fibrous Limestone.—Exists in small deposits between beds of Marl. The fibrous structure is shown in stalactites of caves and in *Oriental alabaster*. Also in *Onyx Marbles* where their colors vary from yellow to green and are translucent.

Some varieties present tints as they are seen in the onyx. The colors of crystalline marbles are red from peroxide of Iron, brown or yellow from carbonate of Iron, green from carbonate of Copper, or black from Carbon.

Compact Limestones.—With grains discernible only under high magnifying power. They have a fracture quite flat and dull; sometimes earthy. Slightly porous. A slightly yellowish variety is employed as a lithographic stone. This includes many varieties of marble, named according to their colors.

Argillaceous Limestone.—A mixture in which clay attains the proportion of sometimes 25 or 30%, at which limit it possesses the most desirable properties for the manufacture of hydraulic

cement. *Albereze* of Florence is a mixture of Calcite and Clay. Clay slates sometimes give limestone a schistose texture. The spotted marbles from Carcassonne are examples. These marbles have red-brown spots, resembling drops of blood. The Campan marbles (Pyrenees) have a schistose texture, and are composed of green or brown slates enveloping veins of white or rose-colored marble. *Cervelas Marble* should be classed here also. The argillaceous material mixed with these limestones may be classed as argillaceous schists.

Siliceous Limestones contain 48% of Silica. They have often a conchoidal fracture. This is the character of the limestone of St. Ouen. Sometimes the Silica is in the form of distinct Quartz grains.

Sandy Limestone.—Sometimes the Quartz envelopes the sand in such quantity and takes such regular crystalline forms, as to justify the impression that it was a sandstone crystallized (*Grès crystallizé de Fontainebleau*).

Glauconitic Limestone is an ordinary Siliceous limestone, containing globules of Glauconite of a blackish or yellowish-green color. It is found in different geological systems; in the Nummulite of the Alps, in the lower limestones of Paris, and in the Silurian in Russia.

Ferruginous Limestone.—Of a brown or yellow color; often porous; compact. It is found in the Transition and Jurassic formations. Ferric hydrate is often found in it.

Travertine.— A compact limestone. Color: grayish, or yellowish-white. It contains cavities which are supposed to have been caused by the escape of carbonic acid, while it was being deposited in the water. The typical form of this rock is the Travertine of Italy, found about Tivoli, also in Elba, where it terminates with the Tuffs.

Limestone Tuff.—Much the same as Travertine, but is lighter and has larger cavities, whose partitions have been formed by the twigs of plants which have disappeared. The sources of water-supply to the baths of San Felippo were strongly charged

with lime, and incrusted everything they flowed over. They produced, according to Lyell, a hard layer of Travertine, 2 kilometres long and about 75 metres wide. In four months a deposit of 30 centimetres thickness was deposited. Their structure has often some analogy to the following rocks:

Pisolite.—Concretions sometimes perfectly spherical which have been deposited in thin concentric layers around some point. They are often bound together by a cement of Lime, more or less argillaceous. The particles are often quite distinct by reason of the different color of the matrix. Certain Brocatelles are of this variety.

Tubercular Limestone.—Cylindrical concretions deposited around stems of plants.

Oolites.—These have a structure like the Pisolites, but have smaller grains. The matrix is sometimes very abundant and may be either earthy or crystalline. This limestone is very abundant in the Jurassic but is found also in other systems.

Stalactite Limestone.—Generally the successive layers may be seen. They are in the form of inverted cones, and are formed of fibres radiating from a common axis. The cone is sometimes flattened in one direction.

Stalagmites are formed on the bottom of caves by the water dripping from the top.

Fresh water Limestone.—This deserves mention, as the term is so often employed by geologists. It bears much resemblance to the Travertine. The limestone of Château Landon is very compact and firm, with holes filled with calc-spar. That of Agen is cellular and bituminous. Sometimes they are marly or silicious, but are nearly always characterized by the presence of fresh water shells.

Shell Limestone (*Coquilliers*).—This comprises all the different deposits which consist of a débris of shells bound by a cement. Example: The Eucrinite limestone, which has a brilliant, sparry fracture.

Calcaire grossier.—A sandy limestone full of shells. Often

very dense. That from Paris is sonorous, and is used in architecture.

Lumachelle.—This name is employed to designate shell limestone, the constituents of which have different colors. That of Astrachan is formed of ferruginous limestone of a deep brown color, with shells of a bright yellow.

Faluns.—A sandy limestone rich in shells, and used as a fertilizer.

Chalk (*Earthy limestone. Calcaire Terreux*).—White; friable, earthy and dull fracture. It is composed of crystalline limestone and minute shells of the foraminifera. It contains flint in nodules, sometimes of a gray or bluish color. In the lower deposits it becomes marly, and contains grains of Glauconite.

Arenaceous Chalk (*Craie Tufau*).—This is sandy and micaceous; of a yellowish or greenish color. Sometimes dense enough to be used for buildings. The rounded pebbles and angular fragments of limestone, united by a cement, form pudding-stones, or limestone breccias. The *Brèche d'Alet* has violet and yellow fragments, and the breccias of Italy and the Pyrenees possess rich and varied colors.

133. **Aragonite.**—The previous description of the mineral may be here recalled. It is distinguished from Calcite by its crystalline form, which is a right prism with a rhombic base; by its higher density (2.93); and by its manner of splitting into small fragments when slightly heated.

134. **Marl** (*Marne, Mergel*).—A homogeneous mixture of clay and lime. Soft; friable; argillaceous odor; sticks to the tongue; fusible, effervesces in acids. Under the action of moisture, it falls into fragments. Density 2.65. The two essential elements are associated in different proportions. They are mixtures themselves of different elements, hence the marls have different properties. Colors: greenish-blue, red, and black. When they contain carbonate of Magnesia, they absorb water with avidity *(Dolomitic Marl)*. The application of the following terms is easily comprehended: Calcareous Marl; Argillaceous

Marl; Sandy Marl; Micaceous Marl; Glauconitic Marl; Carbonaceous Marl; Selenitic Marl; Saliferous Marl. These two last contain Gypsum and Rock Salt.

Oolitic Marl.—A calcareous sandstone formed of grains of oolitic limestone cemented by an argillaceous cement.

Schistose Marl.—Occurs in beds of exceeding thinness, and is found in many sedimentary deposits.

135. **Marl Stone** (*Marnolite*).—A mixture of clay and Marl which seems hardened by a siliceous cement. It is not reduced to a paste by water, but possesses all the other properties of Marl proper.

136. **Giobertite.**—Magnesium Carbonate. ($Mg\ Co_3$). Isomorphous with calcite. Form of cleavage: rhombohedron of $107^\circ\ 25'$. In an earthy state, it is found in great masses. An example of it is exhibited in the white, earthy, Magnesian Carbonate of Baldissero, Piedmont. It dissolves very slowly in hot hydrochloric acid. From this solution, Iron and Manganese can be precipitated. The Magnesium may be easily recognized by the blow-pipe, giving a pale rose color with Cobalt nitrate. The hydrocarbonates of Magnesium give water in the open tube and the reaction as above.

137. **Dolomite.**—Magnesium and Calcium carbonates in nearly equal proportions; isomorphous as Calcite. Cleaves in rhombohedrons of $106^\circ 15'$; density, 2.9; hardness, 3.5 when pure; white, grayish or yellowish color with pearly lustre. It dissolves in nitric acid slowly and without effervescence.

Granular Dolomite.—Color often snow-white. Dissolves in heated nitric acid with effervescence. It is often impregnated with ferruginous clay. The crystalline grains, more independent than in limestone, give the mass a certain flexibility. It is sometimes micaceous.

Accidental minerals: *Mica, Talc, Quartz, Corundum, Amphibole, Spinelle, Graphite, Realgar, Pyrites, Blende, Magnesite,* etc.

Schistose Dolomite is found among the Dolomites of the Jura. It occurs either as subordinate to the Mica Schists, or

Pyrenees; also with the colored Marls, alternating with layers of Rock salt and Gypsum in the Jurassic rocks of southern France.

Oolitic Dolomite.—Common in the Permian of England.

Compact Dolomite.—This has a conchoidal fracture, resembling limestone of the same name, but is readily distinguished by the tests given above for granular Dolomite.

Sandy Dolomite.—A mixture of Dolomite and Quartz sand. Argillaceous Dolomite contains clay.

Dolomite sand.—Isolated grains of Dolomite.

138. **Magnesian Limestone** *(Dolomies Calcarifères).*—Dolomite intimately mixed with limestone. The *Rauwacke* is a limestone rich in Magnesia; hard; compact; of a gray color, spotted with black. Often it is formed of globular masses (Botryoidal Dolomite). It characterizes the Zechstein of Mansfeld and of the Thuringen district of which the other rocks are *Fetid Limestone (Stinkstein);* compact or crystalline; greenish or blackish; exhaling a fetid odor when broken. There is a friable, sandy, Magnesian Limestone termed Asche. These are found also in more recent formations in Savoy and Tyrol.

Cellular Dolomite (*Cargneule*).—A name given in the Alps to Breccias formed of angular fragments of Dolomites or Magnesian limestones.

139. **Apatite.**—Calcium Phosphate. The rock also contains Calcium chloride; Fluorine or Iodine is sometimes found. It fuses with difficulty; colors the flame bluish-green when moistened with sulphuric acid. Dissolved in sulphuric or hydrochloric acid, it yields a white precipitate with Silver nitrate. Mixed in powder with oxide of Copper and treated with salt of Phosphorus, it colors the flame a bluish purple.

Crystalline form: hexagonal prism terminated by a hexagonal pyramid. Large crystals are found in the feldspathic rocks of the United States. A fibrous variety at Crown Point, Essex county, N. Y., is sufficiently abundant to be worked for fertilizing purposes. It is sometimes found in crystalline rocks.

In the Silurian argillaceous schists of Estremadura, it is found in large masses of a fibrous or compact texture, and of a white or yellowish color. It forms a large proportion of the nodules containing the débris of Ammonites at Vissant (Pas de Calais), and forms a geological bed in the clays of part of the Anglo Parisian basin. It has been found in a large number of deposits where its earthy appearance made it difficult of recognition. It sometimes resembles sandstone or millstone; sometimes resinite or calcareous concretions.

Fig. 28.

140. **Guano.**—Accumulations of earthy materials containing Ammonia, Phosphoric acid, Uric acid, Lime, etc. This mixture, of a yellowish, or brownish-gray color, fuses to a kind of scoriæ, and finally becomes white and earthy. It is partly soluble in hydrochloric acid. If treated with potash it releases ammonia.

Analysis of the Guano of the Isle of Chincha, according to Nesbit: organic acids with Ammonia 52.52%; Calcium phosphate 19.52%. Phosphoric acid 3.12%; Alkaline salts 3.56; Silica 1.46; water 15.82%.

Guano also contains the excrements of marine animals and birds and their remains. It covers large areas on the coast of Peru and elsewhere, and is more or less rich in Phosphates and Nitrogenized matter, according as the rains have deprived it of its original constituents.

141. **Sombrerite.**—Hydrated calcium phosphate from the Isle of Sombrero.

142. **Anhydrite.**—Calcium Sulphate ($Ca\,SO_4$). Hardness, same as limestone; heated on charcoal it forms Calcium Sulphide. It has three rectangular cleavages one of which has a pearly lustre. Varieties: (1) *lamellar;* (2) *granular.* Colors: white, bluish, reddish, and smoky-gray. It forms irregular

masses with Rock salt and Gypsum. Often, without changing form, it is transformed into Gypsum by hydration.

143. **Barytine.**—*Heavy Spar.* Barium Sulphate ($Ba\ SO_4$). Cleavable parallel to the faces of a right prism with a rhombic base 101° 42′. (Fig. 29). Hardness 3.5. Density 4.49.

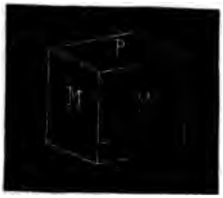


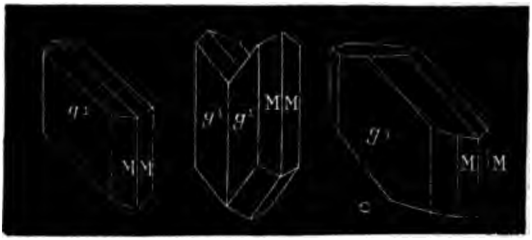
Fig 29.

Varieties: Laminated, globuliferous, fibrous, radiated, concretionary. Colors: white, yellowish, reddish-brown, sometimes colorless. Before the blow-pipe it decrepitates and fuses, and, if mixed with silver chloride, colors the flame yellowish-green. Heated on charcoal, it gives Barium sulphide, which is precipitated white with sulphuric acid by a solution of calcium sulphate.

144. **Celestine.**—Strontium Sulphate. ($Sr\ SO_4$). Cleavable parallel with the faces of a right prism with a rhombic base of 103° 58′. It has a vitreous, slightly pearly lustre, sometimes a pale blue color, sometimes reddish, or white.

Before the blow-pipe it decrepitates and fuses with silver chloride.

145. **Gypsum.**—Hydrated Calcium Sulphate, ($Ca\ SO_4 + 2H_2$). Slightly soluble in water and acids; has a sparry fracture. Form of cleavage: an oblique prism with a rectangular base.



Figs. 30, 31, 32.

One of the three cleavages is easy and parallel to the face g^1. The two other planes of cleavage at 90° from the first make be-

tween them an angle of 114° 9′. Figures 30, 31, 32, exhibit the ordinary forms of the crystal.

Generally the crystals group themselves in pairs, and the twin crystals exhibit the form of a lance-head (Fig. 33).

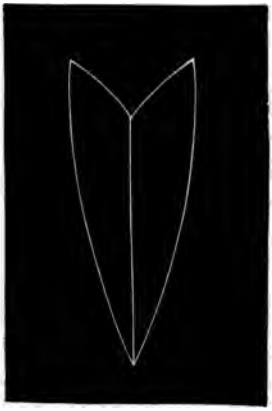


Fig. 33.

Gypsum has a hardness of 2. Heated in a closed tube it loses water and becomes opaque and friable. Heated on charcoal or carbonate of soda it is reduced to calcium sulphate which, if wet with acidulated water, blackens lead paper.

Common varieties: Laminated with a pearly lustre; Silky, with a silky lustre; Saccharoidal, resembling marble; Compact. The laminated varieties are often of a pure white, always dull, but possessing a soft translucency which is much prized (alabaster).

Accidental minerals, occurring with Gypsum: *Rock salt*, *Anhydride*, *Mica*, *Boracite*, *Quartz*, *Pyrites*, etc.

It is found with the Mica schists in the Alps; in the Silurian in Canada; in the Permian of Russia; in the Trias of Mansfeld. In Lorraine, the mass of Gypsum, ramifying at its extremity, has bent the stratified rock which envelopes it.

146. **Glauberite.**—Sodium and Calcium Sulphates. Form: monoclinic prism 83° 20′. Density, 2.7. Vitreous lustre. Color: dirty gray. It fuses easily; colors the flame yellow. Treated with water, Sodium sulphate dissolves out, and Calcium sulphate is precipitated.

CHAPTER XII.

ALUMINOUS ROCKS WITH SILICA

147. **Alunite.**—A compact rock, uniform or porphyroidal, sometimes sandy or brecciated, of a gray, yellow, or red color, and formed of the mineral Alunite. This mineral is a double Sulphate of Aluminum and Potassium. It is infusible, but soluble in sulphuric acid; in the open tube it yields water and Ammonium Sulphate, and, at a high temperature, sulphurous oxide and sulphuric acid. When it is calcined it gives, at first, a sulphurous odor, and then an Aluminic taste.

148. **Aluminite** (Hydrated Aluminum Silicate).—Generally in concretions of a dull white color; soft; earthy, sometimes oolitic; soluble in nitric acid. In the open tube it releases water, and, at a red heat, sulphurous acid. It is found only in nodules or veins in clay.

149. **Beauxite.**—In rounded, granular concretions of a grayish, yellowish, or reddish-white color; distributed through a compact limestone; sometimes in oolitic or earthy masses, generally calcareous. It is an Aluminic and Ferric hydrate of a density of 2.55.

CHAPTER XIII.

METALLIC ROCKS.

Sulphides and Sulpho-Arsenides.

HEATED on charcoal with carbonate of soda, they yield sodium sulphide which blackens lead paper or silver foil. Heated in the oxidizing flame, they yield sulphurous acids.

150. **Galena.**—Lead Sulphide (Pb S). Dominant forms: cube, octahedron, and a combination of these two; sometimes the facets of a rhombododecahedron. It has three rectangular cleavages; a metallic lustre. Color: steel gray; powder: grayish-black. It is easily fused. Heated on charcoal it gives a lead globule and yellow coating. With Potassic bisulphate it yields sulphuretted Hydrogen.

Varieties; Laminated; foliated; granular; compact.

151. **Blende.**—Zinc Sulphide (Zn? S). Dominant forms: rhomboidal dodecahedron, tetrahedron. It has a laminated, fibrous fracture; almost a metallic lustre in the black varieties. Always resinous, analogous to wax. Colors: various; generally, yellow or brown, often black; powder: gray, inclining to brown. Heated on charcoal, it shines brightly, giving a coating, yellow while hot, white when cold. It is colored green by nitrate of Cobalt; is soluble with difficulty in nitric acid; and only fusible on its edges.

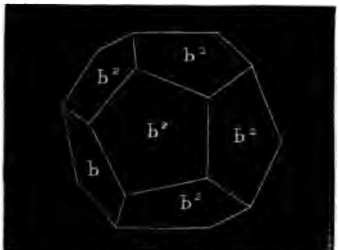


Fig. 34.

Pyrites.—(FeS_2). Ferric Sulphide. Easily reduced to FeS. —

152. **Cubical Pyrites.**—Of a bright yellow color, metallic lustre. Exhibits hemihedral forms. The cubes often have striæ parallel to the edges and perpendicular to the striæ of each adjacent face (Fig. 35). Powder, a brownish-black. Strikes fire with steel.

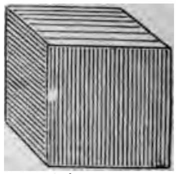


Fig. 35.

153. **Marcasite.**—Of a yellow or pale bronze color, slightly inclined to greenish or white. It crystallizes in orthorhombic prisms, terminated by octahedrons or domes. It has the same composition as the preceding. It is altered to Limonite, sometimes to Ferric carbonate.

154. **Copper Pyrites.** — Chalco-Pyrites. Of a greenish-yellow color frequently showing blue and purple tints; powder of a greenish-black color. Wet with hydrochloric acid it colors the flame green. Fusible to a magnetic globule. With carbonate of soda, it yields a copper bead. Soluble in nitric acid, the solution turning blue with ammonia. It is often a mixture of different sulphides of Copper and Iron. All these sulphides give copper reactions before the blow-pipe or with acids.

Fig. 36.

Metallic Oxides.—The metal can be easily determined by heating on charcoal or by ordinary reactions.

155. **Magnetite.**—(Fe_3O_4) Magnetic oxide of Iron. Forms: octahedron, dodecahedron and a combination of the two. It is quite black in color and reduces to a black powder. Is soluble in boiling hydrochloric acid. Accessory minerals: *Chlorite; Chromic Iron; Garnet; Pyrites; Calcite.*

It exists in stratiform masses in Gneiss and crystalline Schists (Sweden and Norway). In the Ural mountains, large masses are found with the Melaphyres.

156. **Titanic Iron.**—Two forms: one cubical, the other rhombohedric, found usually in blackish-brown grains. Feebly magnetic but acquiring strong power when heated on charcoal. In the phosphorus bead, in the reduction flame, it gives a red color which becomes violet on the addition of Tin.

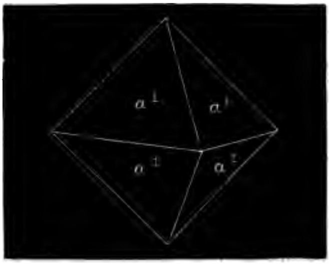


Fig. 37.

157. **Hematite, Oligiste.**—Ferric Oxide (Fe_2O_3). Powder, red or reddish-brown. Pulverized and heated on charcoal, it gives a powder which is magnetic. Slowly soluble in hydrochloric acid, the solution giving reactions for Iron. Dominant forms: rhombohedron of 86° combined with a dihexahedron, with bases of the hexagonal prism, or flat and lamellar following these bases.

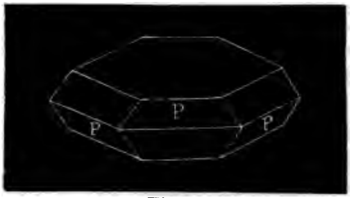


Fig. 38.

Density 5.3; hardness about 6. Sometimes the crystal takes lenticular forms or is reduced to scales (Micaceous Iron ore). Color: black with a bright metallic lustre. The fibrous varieties establish the passage between the preceding forms and the earthy ores.

Earthy varieties have a bright red or brownish-red color; a hardness and density both less than the crystalline forms. They are often mixed with Silica, or are mixed as powder with clays (Ochre). They give the red color to Jaspers, Silica, Sandstone, Marls, and other rocks. The oolitic varieties of a deep or brownish-red color are mixtures of Hematite, Limonite, and a little clay under the form of spherical or lenticular grains, having a density of about 3.

158. **Itabirite.**—A granular aggregate of Micaceous Iron and Quartz, having a schistose texture. Hematite presents it-

self in small scales, isolated, or reunited in a continuous layer which separates equally thin layers of grayish Quartz.

Accessory minerals: *Magnetite, Talc, Chlorite, Native Gold.*

These rocks are developed to a great extent in Brazil, alternating with Quartzites and Itacolumites. They are worked for gold at Villarica.

159. **Limonite.**—Ferric hydrate. In the closed tube it gives water and becomes red. On the coal, it is reduced to magnetic ferrous oxide. It is soluble in hydrochloric acid, depositing sand and clay.

Varieties: Compact L. has frequently a brilliant surface, with a texture somewhat fibrous in rounded nodules in the form of stalactites; some varieties are porous, cellular, or scoriaceous.

Earthy L. of a brownish-yellow or other yellow color, generally mixed with clay and spotted, but reduces to a yellow powder. It is disseminated through a great number of rocks which it colors. It is generally mixed with Silicates and Phosphates. Sometimes this kind takes globular forms, the globules exhibiting concentric layers. One interesting variety, though very impure, is the Limonite of the marshes. It has a greasy resinous lustre, slightly resembling pitch, is compact, somewhat crystalline, often cellular (cloisonnée). It is a mixture of Ferric oxide, Manganic oxide, Silica, Phosphorus, and perhaps Ferric Silicate.

Tapanhoacanga.—Conglomerate composed of fragments of Magnetite, Limonite, Hematite, Quartzite, and Itacolumite cemented by oxide of Iron.

160. **Siderite.**—Spathic Iron ore, Ferrous Carbonate ($Fe\,Co_3$). Isomorphous with Calcite. Density 3.9. Hardness 4. Cleavable in rhombohedrons of 107°. Varieties: (1) Spathic Iron has a yellow or yellowish-gray color with a pearly lustre on a fresh surface. It is generally altered, and becomes reddish-brown or blackish by reason of change to Ferrous oxide. Before the blowpipe it gives a brown or black powder which is magnetic. It is slowly soluble in acids, the solutions giving Iron reactions. It

is found in the Silurian at Styria and it forms masses in the Erzberg. It is found with the Calcites of Zechstein.

(2) *Spherosiderite.*—Rounded concretions with an earthy fracture, generally flat; gray or brown, often containing the remains of fishes, saurians, and prints of leaves and crystals of sulphites or sulphates. Soluble in acids, depositing clay. It is found in nodules in coal beds and in the Lias. It is often mixed with Silica and Manganese.

(3) *Black Band.*—A name given in England to this last kind containing a mixture of Carbon; about 10%.

(4) *Oolitic Iron Ore.* — Generally, altered Limonite.

161. **Manganese Oxides.**—Manganite. Hydrated Manganic Oxide. Orthorhombic prism; generally, splintery or fibrous; yields water in the open tube; brown powder. Gives a green bead with carbonate of soda.

162. **Pyrolusite.**—Manganic dioxide. Differs from preceding only by the angles of the primitive prism, but the powder is black. Often earthy or compact.

163. **Psilomelane.**—Found in mammillary masses with tubercular excrescences, sometimes in stalactite form. Composed of Oxide of Manganese with Baryta and water. Colors: Salt of Phosphorus bead, violet; and Carbonate of Soda, green.

CHAPTER XIV.

COMBUSTIBLE ROCKS.

164. **Sulphur.**— Crystallizes in right octahedrons with rhombic bases. Density, 2.10. Hardness, 2. Very fragile; burns with a blue flame producing sulphurous acid.

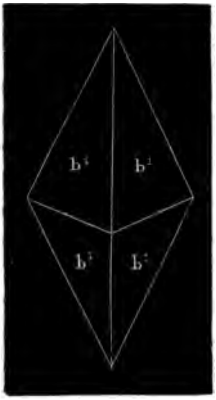


Fig. 39.

165. **Graphite.**—Nearly pure carbon; occurs in hexagonal laminæ of iron-gray color. Metallic lustre. It is scratched by the nail and leaves a mark on paper. It is often mixed with earthy matters. Not attacked by acids; infusible; burns with great difficulty at a high temperature in a current of Oxygen. It is found in veins and masses.

166. **Anthracite.** — Contains 90% of Carbon; is often a mixture of Silica, Alumina, and oxides of Iron. Mean density, 1.4. Semi-metallic lustre a little like that of coke; sometimes it is iridescent. Softer than Calcite and has a conchoidal fracture. It burns in currents of air, and decrepitates in burning. Yields to distillation—water, and a small quantity of non-inflammable gases.

Principal varieties: Scoriaceous A.; Ligniform A.

167. **Bituminous Coal** *(Houille)*. — Brilliant black, often velvety, sometimes like pitch. Heated in a retort, it loses from 9% to 23% of volatile matter. Density 1.35. Powder, black or dark brown. Burns with a flame and yields bituminous odor. When distilled, it furnishes illuminating gas and leaves a porous residue called coke.

The term "bituminous coal" includes many varieties differing in constitution. The maximum amount of Hydrogen is about 6%. Such are termed gas coals. Oxygen varies from 5 to 15%. Among the varieties rich in bitumen is cannel coal. It is compact, fine-grained, breaking with a conchoidal fracture and smooth surface. Burns with a bright flame. Coals are of vegetable origin, and are found widely distributed, especially in the carboniferous system.

168. **Lignite.**—*Brown coal.* Of a brown or pitch black color with a yellowish-brown powder. Lustre dull. Density from 1.1 to 1.3. When once lighted, it continues to burn for some time. When distilled it yields considerable water, bituminous matter, pyroligneous acid, and more wood spirit than ordinary wood. Contains from 55 to 75% of carbon. Varieties: *Compact L.*, susceptible of a fine polish, sometimes used for jewelry (Jet); *Fibrous L.*, in which the structure of the wood is easily recognized; *Earthy L.*, of a blackish-brown which furnishes *Terre d' Ombre*, employed by painters.

169. **Turf.**— Conglomeration of vegetable matter containing about 55% of Carbon. Yields 25% of Tar, and 15% of pyroligneous acid. Burns with or without flame, but with much smoke—giving a peculiar pungent odor. Specific gravity, 1.

170. **Peat** (*Ulmine*).— Remains of vegetables which have become earthy by alteration in marshes. Found in many parts of the world—California, Ohio, Canada, and south of the Caspian Sea.

171. **Bitumens.**—Contain more hydrogen than bituminous coal.

Naphtha is a hydro-carbon, liquid, transparent, light, colorless, and soluble in alcohol. It dissolves the resins and asphalt. It is very inflammable, and in burning yields a thick smoke. Exposed to the air, it becomes viscous, brown, and takes the characters of asphalt. It contains 88% of carbon and 12 of hydrogen.

Petroleum (A mixture of several hydro-carbons). It occurs

as a liquid oil in many parts of the world. It exudes from the surface of the rocks about the Caspian Sea. In the United States it is found with the rocks of the lower Silurian and accumulates in subterranean cavities, from many of which it comes to the surface in springs. In Canada the source appears to be in the lower Devonian. The oil of Ohio, Pennsylvania, and Michigan is supposed, according to Dana, to proceed from the middle Devonian. Sometimes found in more recent rocks even in the Tertiary formation, where it appears to proceed from the decomposition of vegetable matter.

172. **Asphalt.**— Solid bitumen. Black, with brilliant lustre. Has a fracture more conchoidal than coal, burns with a bright flame with much smoke. Dissolves in naphtha and ether. *Pit Asphalt* seems a mixture of Asphalt and Petroleum.

173. **Fossil Resin.**—Amber. Heated in a matrass it fuses at 300°, releasing an essential oil and succinic acid which condenses in the cold part of the tube in needle-shaped crystals. Some rocks contain so much bituminous oil that they are classed as bitumens.

174. **Bituminous Shale.**— (1) *Argilliferous shale*, often fossiliferous, so impregnated with Bitumen as to burn readily. Found in many parts of the world in carboniferous formations.

(2) *Rock Slag.* — Formed of trachytic fragments of a brownish-gray color; burns easily; very rich in bitumen.

(3) Another variety termed *Papier Kohle* is found in laminæ as thin as paper. Burns with a pungent odor. It is of a yellowish or greenish color, and is found in the Tertiary formation at Narbonne.

(4) *Inflammable Marls.*— Found in the vicinity of Grenoble. They inflame easily and effervesce in acids.

Ozokerite.—Is abundant in Gallicia and England near Newcastle. Colorless; yields to the pressure of the hand; has a bituminous but agreeable odor; and is soluble in boiling ether. Burns with a clear flame.

PART THIRD.

METHOD TO BE FOLLOWED IN THE PRACTICAL DETERMINATION OF ROCKS.

§ 1. Globuliferous Rocks: p. 120.

I. With grains harder than the steel point: p. 120.
(A knife blade may be used.)

- A. With vitreous Globules.
  - 1. Radiated texture.
  - 2. Splintery texture.
- B. With crystalline globules.
- C. With irregular grains without intermediate matter.
- D. Globules forming masses irregularly rounded.

II. With grains softer than the steel point: p. 121.

- 1. Effervescing in HCl. No magnetic bead on charcoal.
- 2. Effervescing in HCl. Giving magnetic bead.
- 3. Not effervescing in HCl. Giving magnetic bead.
- 4. No effervescence and no magnetic bead.

§ 2. Cellular or vesicular Rocks: p. 122.

I. A mass forming a paste more or less soluble and fusible: p. 122.

- A. To a colorless glass.
- B. To a black, green, or brown enamel.

II. Masses soluble in acids: p. 122.

- A. With effervescence.
- B. Without effervescence.

III. Infusible and insoluble in acids: p. 123.

IV. Carbonaceous: p. 123.

§ 3. Schistose Rocks: p. 123.

- **I.** Rocks whose chief elements are not so hard as the steel point: p. 123.
  - **A.** Completely schistose.
    - 1. Quite crystalline.
    - 2. Less distinctly crystalline.
    - 3. Of an earthy aspect.
      - *a.* Little or no effervescence in HCl.
      - *b.* Combustible.
      - *c.* Giving effervescence with HCl.
  - **B.** Stratiform: p. 126.
    - 1. Soluble with effervescence in HCl.
    - 2. Slightly effervescent. Magnetic bead.
    - 3. Having neither of these characteristics.
- **II.** Harder than the steel point as to their mass: p. 127.
  - **A.** Entirely schistose: p. 127.
    - 1. Entirely crystalline.
    - 2. Compact and fusible.
    - 3. Compact or earthy and infusible.
  - **B.** More stratiform than laminated: p. 127.
    - 1. Fusible.
    - 2. Infusible.

§ 4. Vitreous Rocks: p. 128.

§ 5. Rocks simple or apparently simple: p. 128.

- **I.** Opaque rocks usually with metallic lustre: p. 128.
  - **A.** Magnetic without having been heated.
  - **B.** Magnetic after being heated.
  - **C.** Neither magnetic nor becoming so.
    - 1. Giving reactions of manganese.
    - 2. Not giving these reactions.
- **II.** With the aspect of carboniferous matter.
- **III.** Stony lustre, not metallic: p. 130.
  - **A.** Softer than the steel point.
    - 1. Crystalline rocks: p. 130.
      - *a.* Soluble in water.
      - *b.* Soluble in sulphuric acid.
      - *c.* Slightly soluble in acid and water.
      - *d.* Soluble in all acids with effervescence.
      - *e.* Reducing to sulphides when heated on coal.
    - 2. Massive texture: p. 131.
      - *a.* Fusible.
      - *b.* Infusible.

- III (continued). Stony lustre, not metallic: p. 130.
  - A. Softer than the steel point: p. 130.
    - 2. Massive texture.
      - *b.* Infusible.
        - *ba.* Making paste with water.
        - *bb.* No paste in water. Insoluble in acids.
        - *bc.* Soluble in acids. Colorless solution.
        - *bd.* Soluble with effervescence to a colored solution.
        - *be.* Soluble with effervescence. Clear.
        - *bf.* Infusible. Nearly or quite insoluble.
  - B. Harder than the steel point: p. 133.
    - 1. Crystalline aggregate.
      - *a.* Fusible.
        - *aa.* Color: clear.
        - *ab.* Granular: yellow, green, brown.
        - *ac.* Black laminated Rocks.
      - *b.* Very slightly fusible.
    - 2. Fine grained or compact.
      - *a.* Fusible.
      - *b.* Infusible.

§ 6. Porphyritic Rocks: p. 135.

I. Harder than the steel point: p. 135.
II. Softer than the steel point: p. 137.
III. Porphyroidal rather than porphyritic: p. 137.

§ 7. Complex Rocks: p. 137.

- I. Crystalline texture.
  - A. Making little or no effervescence in acids.
    - 1. Rocks of a clear color, containing no other black element than mica.
    - 2. Rocks containing at least one black element other than mica.
  - B. Effervescing in acids: p. 140.
- II. Conglomerate rocks, formed of the fragments of one or several kinds of rock: p. 142.

§ 8. Incoherent Rocks: p. 142.

NOTE: The groups of rocks here termed species are only conventionally so called. This is indicated by the definition. These groups include mineralogical aggregations in which the proportions of the elements are not at all constant.

§ 1. Globuliferous Rocks.

I. GLOBULES, HARDER THAN THE STEEL POINT:

A. *Globules* vitreous or enamel-like; scratching glass, having a hardness equal to Orthoclase, but less fusible.

1. Having a radiated texture:

In a vitreous paste, fusing to more or less hollow globules, white or gray. (Spherulitic Obsidian, p. 52.)

Globules in a matrix resembling a tissue of glass threads, cellular, fusible. (Pumice with Spherulites.)

In a porous, sub-crystalline trachytic paste. (Trachyte with Spherulites, p. 49.)

2. Vitreous globules with a membraneous or scaly texture, in a paste easily fusible. (Pearly Retinite, p. 53.)

B. *Globules* of considerable volume formed of crystalline elements, or containing crystals in a fusible paste or in a crystalline fusible rock.

Globules the size of a nut or even of the head, with a porphyritic paste, fusible to a colorless enamel, and filled up with Agate, etc. (Globuliferous Porphyry, p. 45.)

Globules of Orthoclase in a paste formed of Orthoclase and Mica. (Spotted Minette, p. 75.)

The spheroids, quite large, composed of layers, alternately black Hornblende and white Anorthite. (Orbicular Diorite, p. 70.)

Large globules formed of Orthoclase, more or less compact, with a structure often radiated. (Pyromeride Ball Porphyry, p. 45.)

Grains of Oligoclase, whitish, fusible, harder than the steel point; resembling pustules; being apparently partially fused into the matrix. (Variolite, p. 67.)

Nodules of Calcite, soluble with effervescence; or of agate insoluble and infusible, and of greenish earth in a fusible paste. (Spilite, p. 65.)

Irregular nodules of Feldspar, of cubic pyrites in a soft slate which has a somewhat shining lustre. (Nodular Slates, p. 84.)

Nodules of Feldspar in Talcose schist, with a greasy lustre, and a soft feel. (Glandular Talcose schist, p. 81.)

C. *Grains* somewhat regular, aggregated with intermediate paste.

Grains irregular, green, brown, black; crystalline structure, softer than Feldspar, and fusible to black globules. (Augite, Coccolite, p. 60.)

Grains generally of a resinous lustre, about the hardness of Quartz; fusible with difficulty. (Granitite, p. 37.)

D. *Globules* in mammellated masses. Hard, often calcareous, soluble in H Cl, infusible. (Botryoidal Sandstone.)

II. GLOBULES SOFTER THAN THE STEEL POINT:

1. Effervescing in H Cl; round and formed of concentric layers; imbedded in a marly cement; globules, size of a pea. (Pisolite, p. 101.) Globules size of fish eggs. (Oolitic Sandstone.)

Irregular, containing Magnesium and Lime; often cellular. (Oolitic Dolomite, p. 103.)

2. Effervescing with acids, and becoming magnetic when reduced. Solution in H Cl is yellow; is precipitated by Ammonia. (Oolitic Siderite, p. 112.)
3. Becoming magnetic on charcoal; little or no effervescence.

a. Not forming jelly in H Cl; red powder or streak. (Oolitic Iron ore, p. 112.) Yellow or brown powder. (Oolitic Limonite, p. 112.) Powder brown but containing more Alumina than Iron. (Beauxite, p. 108.)

b. Forming jelly in H Cl; blackish or greenish mass, slightly oolitic. (Oolitic Chamoisyte, p. 79.)

Grains generally disseminated through the limestone or sandstone. (Glauconite, p. 78.)

6

4. Not effervescing and not becoming magnetic on coal: White globules; soft to the touch; giving Sulphur fumes in open tube; soluble in HNO_3; often in mammellated nodules. (Aluminite, p. 108.)

Not yielding sulphurous acid. (Globuliferous Clay, p. 86.)

5. Nodules containing crystalline matters; often of greenish earth, in a paste of Melaphyre which has become argillaceous by alteration. The paste sometimes becomes magnetic on charcoal. (Wacke, p. 65.)

§ 2. Vesicular or Porous Rocks.

I. FUSIBLE PASTES, INSOLUBLE OR NEARLY SO IN ACIDS:

A. *Fusible to a colorless glass or to a clear colored enamel.*

Porphyritic paste with cavities, empty or lined with divers crystals. (Vesicular Trachyte, p. 48.)

Vitreous paste resembling a tangle of glass thread. (Pumice, p. 52.)

Semi-vitreous paste, scoriaceous, full of bubbles. (Trachytic Lava, p. 50.)

B. *Pastes fusible to a deep green, brown, or black enamel.*

The cells are generally filled with quartzose substances or crystals.

Hard paste. (Spilites, p. 65.) Softer paste with argillaceous odor. (Wackes, p. 65.)

Scoriaceous masses, full of bubbles. (Lavas, Basaltic Scoriæ, p. 59.)

II. MASSES SOLUBLE IN ACIDS:

A. *With effervescence.*

The solution contains only lime. (Calcareous Tufas, p. 100.)

The solution contains lime and magnesia. (Fetid Limestone, Cargneule, p. 104.)

B. *Earthy masses, soluble in* H Cl. Moistened with H_2SO_4 colors the flame greenish. (Apatite, p. 104.)

Earthy mass soluble in H_2SO_4 yielding in closed tube H_2O and SO_2; the solution giving reactions for Alumina and Potassium. (Alunite, p. 108.)

Mass, more or less easily soluble in H Cl, giving magnetic scoriæ on charcoal; red powder. (Vesicular Hematite, p. 111.)

Same character, brown powder. (Vesicular Limonite, p. 112.)

III. INFUSIBLE CELLULAR MASSES:

Insoluble in acids; harder than Feldspar. Insoluble in Potash solution; crystalline. (Granular Quartz, p. 90.)

Compact; generally opaque. (Millstone, p. 90.)

Soluble in Potash solution. (Geyserite, Silicious Tufa, p. 90.)

IV. CARBONACEOUS MASSES:

Yield Carbonic acid to the blow-pipe. (Scoriaceous Anthracite, p. 114.)

§ 3. Schistose Rocks.

I. EASILY MARKED BY THE STEEL POINT; NOT SO HARD AS GLASS:

A. Clearly Schistose.

1. Decidedly crystalline:

a. Characteristic element, laminated or foliated Graphite of a lead color, soiling the fingers, burning with difficulty, and not attacked by acids. (Graphite Schists, p. 114.)

b. Characteristic element, Gypsum, scratched by thumb nail, yielding H_2O in closed tube, becoming opaque. (Laminated Gypsum, p. 106.)

c. Characteristic element, Talc; greenish or yellowish-white; scratched by thumb nail, slightly fibrous, insoluble, infusible, yielding a little H_2O in open tube, Talcose. (Schist, p. 81.)

d. Characteristic element, a chloritic element, more or less

deep green, in laminæ, greasy lustre, in masses, somewhat fissile; attacked by H_2SO_4, yielding reactions for Silica, Alumina, Magnesia, Iron, H_2O. (Chlorite Schist, p. 78.)

e. Talc mixed with chlorite as a distinct element, associated also with Feldspar and Quartz. (Schistose Protogine, p. 39.)

f. One of the distinct elements is Mica associated with Feldspar and nearly always with Quartz.

In any irregular fracture of the rock, Feldspar is easily recognized.

Mica easily recognized by the laminæ. (Gneiss, p. 42.)

g. Characteristic element, Potash Mica, very abundant; forms minute scales united in layers, alternating with grayish laminæ of granular or compact Quartz, rarely of Feldspar, (Mica Schist, p. 74.)

Potash Mica mixed with ferro-magnesic Mica, in laminæ, often hexagonal, difficult to fuse. (Mica Schist with Magnesia-Mica, p. 74.)

h. Hydrated Mica not containing Magnesia, in strong pearly scales. Fusible before blow-pipe. Attacked by H_2SO_4 before heating, not afterwards. (Mica Schist with Damourite, p. 75.)

Mica with little lustre, rich in soda, without magnesia, but sometimes with Staurotide and Disthene. (Mica Schist with Paragonite.)

Mica Schist containing crystals of Macle (Macliferous Mica Schist.)

2. Crystalline structure less apparent :

a. Characteristic element; Serpentine, soft to the touch, reducing to a soft powder, yields H_2O in a closed tube, blackens before the blow-pipe, fuses with difficulty, decomposed by HCl and H_2SO_4.

Rock not divisible into laminæ. It has a marked greasy lustre, sometimes somewhat resinous. (Schistose Serpentine, p. 80.)

b. Rock very fissile, divisible into laminæ, soft, with a silky lustre; more or less easily fusible, yielding a soft powder. (Argillaceous Mica-Schist, p. 84.)

Analogous rock, more compact, with a shining lustre; smooth fracture, very fissile, very coherent even in thin laminæ. (Roofing Slate, p. 85.)

Same rocks, same lustre, with a rather splintery fracture, not quite as fissile and a little harder. (Novaculite, Whetstone, p. 85.)

Slate with crystals in long whitish or grayish, incomplete prisms, often in crosses; infusible, giving the rock a rugose texture, and uneven surface, sometimes forming earthy blackish spots. (Chiastolite Schist.)

Slate with orthorhombic prisms of Staurotide; reddish-brown color, six faces, infusible, slightly attacked by H_2SO_4. (Staurotide Schist, p. 84.)

Rocks often very schistose, fine grained, soluble with effervescence in H Cl. (Schistose Dolomite, p. 103.)

3. Rocks of an earthy aspect:

a. Making little or no effervescence in H Cl; fusible, divisible into laminæ, having an argillaceous odor, and a dull color. (Common Clay Slate, p. 85.)

Same rock, colored black by carbon, containing Aluminum sulphate. (Carboniferous Clay Slate. Ampelite, p. 85.)

Quite schistose, forming jelly with HCl, sticking to the tongue. (Magnesian Clay Slate.)

Extremely schistose, fissile, burning with flame and bituminous odor, leaving a clay residue. (Bituminous Schist, p. 116.)

Schist composed of grains of quartz, scales of mica, and a clayey cement colored yellow or red by oxide of Iron, or blue or green by carbonate of Copper. (Psammites, p. 93.)

b. More or less finely schistose, combustible, burning without residue. (Leaf Coal.)

c. Effervescing in H Cl.

In cold H Cl leaving clay residue. (Schistose Marl, p. 102.)
Dissolves in hot H Cl, leaving no residue. (Schistose Dolomite, p. 104.)

Effervescence somewhat prolonged, argillaceous odor; formed of Quartz Mica, and a marly cement. (Macignos, p. 93.)

B. *Sedimentary Rocks*, stratified in not very thick layers, but not in laminæ.

1. Soluble in acids, precipitated by ammonia. (Travertines, p. 100.)

Without sensible cavities, more or less argillaceous. (Sedimentary Limestone, p. 99.) Leaving clay residue. (Marls, p. 102.)

Soluble in hot acids, yielding solutions for Magnesia. (Stratified Giobertite, p. 103.)

2. Little or no effervescence, and becoming magnetic on Carbon. (Sedimentary Hematite, p. 111.)

Yellow or brown powder. (Sedimentary Limonite, p. 112.)

3. Little or no effervescence in H Cl, not becoming Magnetic.

a. Fusible.

Argillaceous odor, insoluble, always fusible to a clear or whitish bead, rock sometimes nearly compact, often fossiliferous. (Eurite, p. 43.)

Grayish rock, friable or solid, having the aspect of volcanic mud, with vitreous Orthoclase and Mica, fusible. (Trachytic Tufa, p. 54.)

Analogous rock with fragments of Pumice. (Trass, p. 55.)

b. Fusible with difficulty, or not at all.

Argillaceous odor, sticks to the tongue, slightly soluble. (Sedimentary Clays, p. 87.)

Rock with argillaceous odor, a somewhat jaspery appearance, divisible into fragments more or less polyhedric. (Argillite, p. 86.)

The following materials may be enumerated as belonging with this class, but they are rarely found in large masses:

c. Earthy Baryta or Barytine. Insoluble, infusible; powdered and treated with carbon may be reduced to Barium Sulphide.

d. Massive Apatite, soluble in acids.

e. Calamine, the powder of which, if heated with nitrate of Cobalt becomes yellowish-green.

f. Concretionary Blende which yields sulphurous acid on

carbon and gives a coating on charcoal which is yellow while hot, but white when cold. Generally associated with Galena.

g. Concretionary Aragonite, fibrous, decrepitates before the blow-pipe; soluble with effervescence in cold acids.

II. SCRATCHED WITH DIFFICULTY BY STEEL POINT, SCRATCH GLASS EASILY:

(When rocks are friable, the hardness of their grains may be tried between two plates of glass.)

A. Completely schistose or foliated.

1. With elements visibly crystallized. With a base of Hornblende, laminated or acicular; fusible to black or deep green enamel. (Hornblende Schist, p. 69.)

With a base of green Hornblende, fusible to an enamel not so deeply colored. (Actinolite Schist, p. 69.)

With a base of Hematite which becomes magnetic on charcoal, in black grains of metallic lustre. (Itabirite, p. 111.)

With infusible Quartz grains in layers, separated by Talc or Mica. (Quartzites and Itacolumites, p. 90.)

2. Compact and fusible, crystalline paste, partly soluble in H Cl, divisible into sonorous plates, often overspread with crystals of Sanidine. (Phonolite, p. 51.)

Crystalline paste, insoluble in H Cl, frequently covered by crystals of Feldspar and Quartz. (Slaty Porphyry, p. 45.)

3. Compact or earthy, infusible, in more or less thin laminæ; hard, insoluble in H Cl and hot alkaline solutions. (Argillite, p. 86.)

In minute infusible grains, insoluble in H Cl, but soluble in hot alkaline solutions.

B. Rocks stratified rather than laminated.

1. Infusible. Soluble in hot alkaline solutions, concretionary. (Geyserite, p. 91.)

2. Fusible. Feldspathic paste, with splintery fracture. (Petrosilex, p. 43.)

Feldspathic paste, infusible, insoluble, porous. (Schistose Trachyte, p. 48.)

Paste deep green, fusible to black globule. (Aphanite, p. 71.)

Aspect vitreous, partly enameled, fusible with intumescence to clear colored glass. (Retinite, Pitch Stone, p. 53.)

Vitreous or enameled, fusible to green enamel. (Vitreous Basalt, p. 56.)

With acicular crystalline grains forming scoria before the blow-pipe, attacked by H Cl after calcination. (Stratified Epidote, p. 73.)

Crystalline grains, attacked by HCl, after long calcination; hard as Quartz . . . Crystals of the cubic system. (Garnet, p. 72.)

Rocks formed of a white material, fusible, attacked by H Cl and by H_2SO_4 containing green Smaragdite. (Euphotide, p. 66.)

§ 4. Vitreous Rocks.

Resinous aspect, fuse easily with intumescence, fracture splintery, yield H_2O in open tube. (Retinite, p. 53.)

Vitreous rocks with conchoidal fracture fusible to blebby globule. (Obsidian, p. 52.)

Fusible to a black globule, partly soluble in H Cl. (Vitreous Basalt, p. 59.)

Rock resembling porcelain or burned clay, often banded, fusible. (Porcelanite, p. 86.)

Vesicular rocks and Globuliferous rocks may be included in this group.

§ 5. Rocks simple or apparently so.

I. OPAQUE WITH METALLIC LUSTRE GENERALLY:

Solutions in acids strongly colored; depositing only sand or clay.

A. *Magnetic*, of black color and giving black powder; hardness 6; density 5.18. Soluble in hot HCl, grains often octahedrous. (Magnetite, p. 110.)

Same characters, giving a violet bead with salt of Phosphorus. (Titanic Iron, p. 110.)

Brown powder, green bead with salt of Phosphorus. (Chromic Iron, p. 110.)

B. *Magnetic*, only after being heated on carbon; having metallic lustre, black, or iridescent; also earthy red varieties; powder, red or purplish. (Iron peroxide, Hematite, p. 111.)

Exterior shining, sometimes iridescent, or earthy and yellow, mammellated, powder brown or ochre-yellow. (Limonite, p. 112.)

Effervescing in H Cl, sparry fracture. (Siderite, p. 112.)

Earthy aspect, sometimes slightly metallic; blackish color, powder greenish-gray, fusible to black magnetic scoria, soluble in H Cl, with a deposit of gelatinous Silica, not so hard as a steel point. (Chamoisyte, p. 79.)

C. *Not Magnetic; not becoming so.*

1. Giving Manganese colored bead with salt of Phosphorus. Releasing Chlorine in the presence of H_2SO_4 and NaCl.

a. Black powder, infusible; density 4.97. (Pyrolusite).

b. Black powder, yielding H_3O in closed tube; density 4. (Manganite, p. 113.)

c. Brownish-black powder; density 4.33. Solution in HCl precipitated by H_2SO_4. (Psilomelane, p. 113.)

2. Non-Manganic rocks. Lead-gray or black. Powder, blackish-gray. Lead reaction on coal. (Galena, p. 109.)

Color variable; powder gray or brown; heated with carbonate of Soda forms a sulphide which blackens silver foil. Coating on charcoal, yellow while hot; white when cold; fusible, attacked by $H NO_3$. (Zinc Blende, p. 109.)

Lead-gray or black; scratched by thumb nail; marking paper. (Graphite, p. 114.)

Brass-yellow; hardness 6.5; cubical crystals, fusible, soluble, magnetic before the blow-pipe, is found sometimes nearly altered to Limonite or Hematite. (Cubical Pyrites, p. 110.)

Color greenish-yellow. Soluble in $H\,Cl$, yielding copper reaction with Ammonia; hardness 4; density 4.16. (Chalco-Pyrites, p. 110.)

Red powder; volatilizes in open tube, becomes black at a high temperature but red again on cooling; heated with carbonate soda yields metallic Mercury and Sodium Sulphide. (Cinnabar.)

II. CARBONACEOUS MATERIALS:

Often brilliant lustre, sometimes dull; fibrous texture; will detonate in tube with $K\,NO_3$. (Fossil Carbons.)

III. ROCKS WITHOUT METALLIC LUSTRE:

A. *Not so hard as the steel point.*

1. Crystalline:

a. Soluble in water; saline taste; colors flame yellow. (Rock Salt, p. 96.)

Solution precipitated by Silver Nitrate and Platinum Chloride. (Carnallite, p. 97.)

Salt burns fiercely on coal. (Nitre, p. 96.)

Colors flame yellow. (Soda Nitre, p. 96.) Colors flame yellow and effervesces in acids. (Trona, p. 96.)

b. Insoluble in H_2O. Soluble in $H_2\,SO_4$ but without releasing CO_2. Fuses easily. Colors flame yellow. Cleavage rectangular. (Cryolite, p. 97.)

Corrodes glass. Solution in $H_2\,SO_4$ precipitated by Ammonium Oxalate. (Fluor Spar, p. 98.)

Soluble in $H\,Cl$ and $H\,NO_3$; giving yellow precipitate with Silver Nitrate; colors flame pale green. (Apatite, p. 104.)

Rock often porous; heated in open tube, gives water and sulphurous acid; soluble in Potash solution. (Alunite, p. 108.)

Rock formed of crystalline laminæ often greenish, attacked by $H\,SO_4$; soft powder, gives water in closed tube, fusible when rich in Iron. (Chlorite Schist, p. 78.)

c. Insoluble or nearly so in water; soluble in dilute acids without effervescence.

Solution giving white precipitate with Ammonium Oxalate. (Limestone.) Soluble in acids depositing clay. (Marl, p. 102.)

Soluble as before, depositing silica. (Siliceous Limestone, p. 100.)

Depositing schistose materials. (Schistose Limestone, p. 100.)

Dissolving slowly in cold acid; solution precipitated by Ammonia and Sodium Phosphate. Before the blow-pipe giving flesh-tint with Cobalt nitrate. (Magnesite, p. 103.)

In addition to above reaction, the solution gives precipitate of Calcium with Ammonium Oxalate. (Dolomite, p. 103.)

Solution gives brown precipitate by Ammonia and red with Potassium Sulpho-cyanide. (Siderite, p. 112.)

Yielding many of the preceding reactions. (Brown Spar.)

Quite soluble with heat. (Magnesian Limestone, p. 104.)

d. Insoluble or nearly so in H_2O and acids, either before or after heating.

Compact, soft to the touch, scratched by the nail. (Steatite, p. 82.)

Soft to the touch, soluble in concentrated H_2SO_4 (Serpentine, p. 81.)

e. Yielding Sulphides when heated on carbon.

Scratched by the nail; before the blow-pipe it exfoliates and becomes opaque; yields Calcium Sulphides when heated on charcoal. (Gypsum, p. 106.)

Not scratched by nail, fusible, wet with H Cl, colors the blow-pipe flame brick-red. (Celestine, p. 106.)

Heated before the blow-pipe is only rounded on the edges and decrepitates, cleavage oblique; density above 4. (Heavy Spar, Barytine, p. 106.)

Fuses with difficulty to white enamel and dissolves in Borax to a clear bead which becomes yellow on cooling. (Anhydrite, p. 105.)

2. Massive texture:

Earthy aspect, often argillaceous odor.

a. Fusible with difficulty, full of cavities, composed of Feldspar partly altered. (Argillaceous Pitchstone, p. 53.)

Fusible, grayish, often containing crystals of Sanidine. (Oligoclase-Trachyte, Domite, p. 48.)

Fusible, stratiform, without apparent cavities, sedimentary. (Eurite, Felstone, p. 43.)

Fusible, ferruginous, attacked by H Cl. (Bog Iron ore.)

Fusible, sticking to the tongue, falling apart in the water. (Fuller's Earth, p. 87.)

Fusible, argillaceous odor. (Argillite, p. 86.)

Disengages Hydrofluoric acid when treated with H_2SO_4 (Fluor Spar, p. 98.)

Giving colored solutions with acids. (Magnetite, Limonite, p. 112.)

Fusible to black magnetic scoria; gives yellow solution with H Cl, depositing gelatinous Silica. (Chamoisyte, p. 79.)

b. Infusible:

ba. Forming paste with water, decomposed by H_2SO_4; contains Silica, also some Quartz; yields a non-plastic paste. (Kaolin, p. 86.)

Yields to H Cl Alumina and Iron; gives a plastic paste. (Plastic Clay, p. 86.)

bb. Not forming paste in water, insoluble in acids, soluble in boiling Potash, friable mass, slightly consistent; will scratch glass. (Siliceous Earth, p. 91.)

bc. Colored masses giving colored solutions with acids. See Simple rocks.

bd. Soluble with effervescence in H Cl, giving Iron reactions. (Siderite, p. 112.)

bc. Soluble in cold dilute acids with residue of Silica. (White Chalk, p. 102.)

Same with granules of Glauconite. (Glauconitic Chalk.)

Same with residue of sand and Mica. (Chalk Tufa.)

Rock more compact than above. (Compact Limestone, Compact Chalk, p. 102.)

With little effervescence, leaving residue of clay. (Marl, p. 102.)

bf. Infusible, no effervescence, non-argillaceous, insoluble; treated with charcoal and heated, yields Barium sulphide. (Heavy Spar, p. 106.)

Scratched by the thumb nail, slightly soluble, fusible, (Gypsum, p. 106.)

B. Rocks harder than the steel point.

1. Aggregate of crystalline grains:

a. Fusible, giving globule.

aa. Color neither black nor deep green; the essential element has the laminated fracture of Feldspar.

This element is insoluble, it presents faces of considerable size; bright lustre, containing about 66% of Silica sometimes colored green by oxide of Copper. (Harmophanite, p. 41.)

Essential element, Orthoclase with small facets, the rock being nearly compact. (Leptynite, Granulite, p. 41.)

Chief element, Oligoclase, striated, insoluble, fusible, cleavable; contains 60% of Silica, mixed with Feldspar, Quartz, and Hornblende. (Tonalite, p. 71.)

Essential element, Labradorite; fusible, attacked by acids after being pulverized, striated laminæ. (Labradorite, p. 41.)

ab. Rock formed of greenish-yellow or brown grains.

The grains are Pyroxene, easily fused, not attacked by acids; hardness about that of Feldspar; density 3.3. (Coccolite.)

Grains with difficulty, belong to the garnets; generally harder than Quartz; slowly attacked by acids, but forming a jelly after calcination; density 3.4 to 4.3. Rock often compact. (Garnet, p. 72.)

Fine grained, form a jelly in HCl after calcination, are of a pistache green color, fusible to a black enamel; density 3.4; hardness about 6. (Epidote, p. 73.)

Grayish rock, fusible, soluble in acids; density 3. (Scapolite, p. 72.)

ac. Foliated black rocks, fusible, soluble in HCl, two cleav-

age-planes forming an angle of 124°. Thin laminæ of a deep green. (Amphibolite, p. 69.)

b. Formed of crystalline grains, fused with difficulty or not at all.

Rocks formed of green or yellowish-green Peridot, infusible, soluble in H Cl after pulverization. (Dunite, p. 80.)

Rock formed of grains having a sparry fracture of a white or greenish-white color, a greasy lustre fusible only at the edges, not attacked by acids. (Enstatite, p. 33.)

Foliated or granular rocks formed of Hypersthene, fibrous, brown or with a coppery lustre; not attacked by acids. (Hyperite, p. 67.)

Rock consisting only of Quartz, infusible, insoluble, greasy lustre, translucent, vitreous fracture. (Quartz Rocks, p. 90.)

Rock formed of Quartz grains sometimes very fine, united by a cement difficult to distinguish; resembling Quartzite but generally colored by oxides of Iron; massive, and mammellated. (Sandstone, p. 92.)

Same rock with siliceous cement, conchoidal fracture and shining lustre. (Siliceous Sandstone, p. 92.)

Aggregate of Quartz grains; infusible, insoluble in acids; differing from sandstone only by the absence of cement. (Quartzite, p. 90.)

2. Rock formed of an element in crystalline grains, but of indistinct form by reason of their minuteness.

a. Fusible.

Fusible to a white enamel, more or less dotted with black; insoluble; with a crystalline structure, rough, porous, and grayish. (Trachytes, p. 48.)

Fusible to a greenish-white or brownish-green enamel, forming jelly in acids; sonorous. (Phonolite, Clink-Stone, p. 51.)

Fusible to a white enamel, sometimes spotted with black; insoluble; generally the rock is compact, of a clear color, sometimes of a more or less reddish-brown, with a splintery fracture, and containing frequently crystals of Orthoclase. (Eurite, Petrosilex, p. 43.)

Rocks generally of a black or dark color, fusible to dark colored globules.

Rocks difficult to fuse, greenish, decolorized by HCl, or black, often shining; often attacked by acids; formed of Hornblende and Oligoclase in indistinct masses; allied to the Diorites; often containing crystals of Hornblende. Density, 2.75 to 3. (Aphanite, p. 71.)

A blackish rock, fine grained, brilliant lustre, formed of Labradorite and Augite, allied to the Dolerites; if pulverized and treated with acids, $\frac{1}{4}$ of the mass is dissolved. Density 2.9 to 3. (Anamesite, p. 56.)

Compact rock, bluish or grayish-black color; dull, tenaceous; pulverized and digested in HCl, it loses $\frac{1}{2}$ to $\frac{3}{4}$ of its mass; contains Labradorite, Augite, and Titanic Iron. Density 2.5 to 3. (Basalt, p. 56.)

Compact rock, formed of Hypersthene and Labradorite. The residue, after treating with acids, is difficult to fuse. (Hyperite, Hypersthenite, p. 67.)

b. Infusible, insoluble, and but slightly, if at all, soluble in boiling potash. Splintery or conchoidal fracture translucent on the edges. (Flint, p. 90.)

Flat fracture, opaque. (Jasper, p. 91.)

Granular aspect in the fracture (Quartzite and Sandstone.)

Infusible and friable, hard enough to scratch glass, insoluble in acid, but soluble in potash solution. (Siliceous Sinter, p. 91.)

§ 6. Porphyritic Rocks.

Rocks formed of a paste always fusible, and of crystals or grains of Feldspar, Augite, Hornblende, Quartz and scales of Mica.

I. *Pastes harder than the steel point:*

Fusible to white globules sometimes dotted with black; or to bottle-green beads, if much Iron be present.

Paste abundant, with crystals of Orthoclase with bright lustre, never striated; mixed also with crystals of Oligoclase duller in color and softer, often with striæ; often also Albite of a clear color, with or without laminæ of Mica. (Porphyry proper, Feldspathic Porphyry, p. 45.)

Quartz crystals in dihexahedrons added to the above. (Quartziferous Porphyry, p. 43.)

Paste indistinct, crystals of Feldspar, Quartz and Mica. (Granitoid Porphyry, p. 45.)

Paste distinct, Feldspar crystals apparently Oligoclase, striated, often with Quartz and often small quantity of Hornblende, Augite, Mica in scales, Chlorite. (Oligophyre, p. 46.)

Paste more or less porous, rough to the touch, with crystals of Oligoclase, Hornblende or Augite. (Andesite, p. 50.)

Paste fusible to a white globule, dotted with black, with crystals of Sanidine, often Hornblende and Mica. (Porphyritic Trachyte, p. 48.)

Greenish paste fusible to a white globule, partly soluble in HCl. (Porphyritic Phonolite, p. 51.)

Pastes fusible to black or dark colored globules:

Dark paste often magnetic, containing crystals of Augite exhibiting a characteristic form; often colored green by Chlorite, and is calcareous. (Melaphyre and Green and Black Porphyries, p. 62.)

Paste with crystals of Oligoclase and Hornblende. (Dioritic Porphyry, p. 71.)

Basaltic paste, fusible to a black enamel, with grains of Olivine, infusible, soluble in HCl; also Peridot in greenish or reddish grains. (Olivine Basalt, p. 56.)

Basaltic paste with crystals of Hauyne in rhombododecahedrons, generally blue; vitreous fracture, fused with difficulty, reduced to jelly in HCl. (Hauynophyre, p. 60.)

Basaltic paste with crystals of Amphigene in reddish or white trapezohedrons, infusible, soluble in acids. Rock of a more or less deep gray color. (Leucite Porphyry, p. 44.)

Basaltic paste with crystals of Nepheline in six sided prisms, easily fusible, yield gelatinous deposit in H Cl. Rock often granular. (Nepheline Dolerite, p. 56.)

Paste of Oligoclase with brown or black Mica and Spathic Iron; Oligoclase crystals. (Kersanton, p. 76.)

Same rock with crystals of Hornblende. (Kersantite, p. 77.)

Orthoclase paste sometimes contains crystals of this Feldspar, considerable brown or blackish Mica and a little altered Hornblende. (Minette, p. 75.)

II. *Paste softer than the steel point*, by reason of alteration:

Argillaceous Porphyry; Domite. (See *Earthy rocks.*)

Vitreous rocks with crystals of Feld: Obsidian, Retinites. (Gallinace, p. 59.)

III. *Rocks of a porphyroidal rather than a porphyritic aspect:*

Calcareous rocks effervescing with acids and containing Garnets. (Calciphyre.)

Calcareous rocks effervescing with H Cl, containing Serpentine. (Ophicalcite.)

Limestone with Mica or Talc. (Cipollino, p. 99.)

Limestone with Hornblende. (Hemitrene.)

Schists with Ottrelites, p. 84.

" " Staurotides, p. 84.

" " Macles, p. 84.

With the above might also be classified those Syenites, Granites, and Gneiss which contain large crystals of Feldspar disseminated through a matrix of finer grains and hence called Porphyroidal.

Related to these also are the Wackes and the Spilites.

See Globuliferous and Cellular rocks.

§ 7. Complex Rocks.

I. TEXTURE ENTIRELY CRYSTALLINE:

A. Non-calcareous; making little or no effervescence in acids.

1. **Rocks of clear color, or containing only black Mica, as an essential element:**

Orthoclase in small laminated grains with Garnets and black Tourmalines. (Leptynite, Granulite, p. 41.)

Orthoclase in spathic laminæ, bright, more or less pearly, yellow, red, or green; fusible, insoluble in acids; Quartz in vitreous grains, often in long hexagonal prisms; often arranged in hieroglyphic forms. Tourmaline, Beryl and Mica sometimes occurring as accessory elements. (Pegmatite, p. 40.)

Same elements, but more or less rounded, united by a visible cement; often contains particles of Galena, Chromic oxide and heavy Spar. (Arkose, p. 92.)

Orthoclase, white, red, and green, with a bright lustre on the fracture surface; often Oligoclase with a splintery fracture, a duller lustre and either white or slightly greenish Quartz in vitreous grains; Mica, of a silver white, yellow or black color. (Granitite, p. 37.)

Same rock with Mica replaced by Talc; very soft, insoluble, and infusible; accessory element, Chlorite. (Protogine, p. 39.)

Orthoclase, Nepheline, fusible with difficulty, soluble to jelly in H Cl, HC; black Mica in large laminæ; accessory element, Sodalite. (Miascite, p. 41.)

Orthoclase, Elæolite. (Variety of Nepheline.) Blue Sodalite. (Ditroite, p. 41, rather rare.)

Oligoclase in crystals, fusible, insoluble; Mica of a bronze color, rock porphyroidal. (Kersanton, p. 76.)

Saussurite. (Labradorite or Zoisite) dull, greenish-white; density about 3, difficult to fuse, forming jelly in H Cl; Smaragdite of a green color, easily fusible. (Euphotide, p. 66.)

Labradorite with Diallage of a pearly lustre more or less silky, soft, easily fusible, not attacked by acids. (Gabbro, Granitone, p. 66.)

Quartz in grayish grains, infusible, insoluble; with Mica in laminæ. (Greisen, p. 74.)

Quartz with Topaz in crystals of a pale yellow color, often with black Tourmaline and Lithomarge. (Topaz rock, p. 89.)

Garnets withActinolite and Talc. (Garnet rock, p. 72.)

Aggregate of red Garnet, harder than Quartz with Pyroxene, insoluble, softer than Garnet; sometimes blue Disthene and green Epidote. (Eklogite, p. 72.)

Disthene, infusible, insoluble, barely scratched by the steel point, with Garnet, and Augite. (Disthene, p. 72.)

Aggregate of Cordierite in hexagonal prisms with a vitreous fracture, blue in certain directions, difficult to fuse, attacked slightly by acids, harder than Quartz; Orthoclase and Garnet. (Cordierite, p. 41.)

Mica, Garnet and Iolite. (Kinzigite, p. 42.)

2. Rocks containing at least one black or deep green element other than Mica.

White rock spotted with black or *vice versa*. Oligoclase in white, greenish-white, or reddish-white grains, fusible, insoluble; black or deep green Hornblende in grains, very fusible, brilliant cleavage faces forming an angle of 124°; Epidote and Pyrites. (Diorite, p. 69.)

Rock similar, white or grayish-white Labradorite, Augite in black grains or in crystals of a vitreous fracture and imperfect rectangular cleavage; crystals of Magnetite; the rock often effervescing in acids. (Dolerite, p. 56.)

Oligoclase, Quartz, Mica, and Hornblende. (Tonalite, p. 71.)

Oligoclase, Mica, Hornblende, rock generally porphyritic. (Kersantite, p. 77.)

Oligoclase, Hornblende, forming a rock sometimes porphyritic, sometimes granular, often showing by its porosity, its analogy to the Trachytes. (Hornblende-Andesite, p. 50.)

Same rock with Augite replacing the Hornblende, sometimes also Peridot. (Augite-Andesite, p. 51.)

Labradorite, Augite, Magnetite, rock impregnated with Chlorite and Calcite. (Ophitone, p. 61.)

White or gray Anorthite, fusible, soluble in HCl depositing Silica, Hornblende of a deep green, and a little Quartz. (Orbicular Diorite, p. 70.)

Granulated rock, often porphyroidal with white Anorthite, and black Augite: Hornblende and Epidote as accessory elements. (Eukrite, p. 61.)

Hypersthene of a brownish or greenish-black, with Labradorite of a greenish-white color. (Hyperite, p. 67.)

Quartz and Tourmaline, the latter black and fusible and in a scoria of the same color. (Tourmaline rock, p. 34.)

Granite with a large quantity of Acicular Tourmaline. (Tourmaline Granite, p. 38.)

B. Effervescing with acids, and formed:

1. Of crystalline limestone which effervesces promptly with acids, giving a solution precipitated by Ammonium Oxalate; or of Dolomite which dissolves with effervescence only with heat.
2. Of a large number of accidental minerals.

II. CONGLOMERATE ROCKS.

Formed of fragments of one or many rocks, generally united by a cement:

Angular fragments of Granite in a matrix which differs only by the color or dimensions of its particles. (Granitic Breccia, p. 39.)

Angular or rounded fragments of Porphyry in a matrix of the same kind. (Porphyritic Breccia, p. 46.)

Fragments of Trachyte in a sort of Trachytic paste. (Trachytic Breccia, p. 54.)

Fragments of Phonolite in a paste of Feldspar more or less Kaolinized. (Phonolitic Breccia, p. 51.)

Débris of Melaphyres, Spilites, Wackes, Ophitone, in a brown, green, or gray paste, like those of the Porphyries, but with more calcareous matter. (Melaphyre conglomerates and Breccias, p. 62.)

Débris of Basaltic character. (Basaltic conglomerates, p. 56.)

Same débris with cement of Palagonite. (Palagonitic Tufa, p. 61.)

Débris of Schistose crystalline rocks in an argillaceous paste. (Gneiss and Mica Schist conglomerates, p. 39.)

Fragments of Quartz in a siliceous cement often ferruginous. (Quartz Breccia, p. 94.)

Fragments of Jasper or Flint in a siliceous cement. (Jasper Breccia, p. 94.)

Rounded pebbles of Flint in siliceous cement. (Puddingstone, p. 94.)

Pebbles of Porphyries more or less altered, argillaceous cement. (Psephite, p. 95.)

Quartz in pebbles or grains, particles of clay Slate of Phtanite, with a cement and Silica containing free Carbon. (Graywacke, p. 94.)

Fragments of Sandstone, Limestone, crystalline schists, with siliceous, argillaceous, or calcareous cement with a surface presenting rounded projections. (Nagelflue, p. 94.)

Quartz, Feldspar, sometimes Mica in a cement siliceous, or argillaceous, or formed partly of Heavy Spar or Fluor Spar. (Arkose, Feldspathic Sandstone, p. 92.)

Quartz fragments with calcareous or argillaceous cement. (Sandstone, p. 92.)

Quartz grains, flakes of Mica, with particles of Feldspar, argillaceous cement, colored by oxide of Iron, or Copper carbonates, schistose texture. (Psammite, p. 93.)

Same rock with carbonaceous particles. (Carbonaceous Sandstone, p. 92.)

Grains of Quartz and Feldspar, laminae of Mica with a greenish gray cement of a siliceous, marly character; a solid rock more or less schistose and effervescing in acids. (Macigno, p. 93.)

Grains of Quartz, Calcite, Mica Glauconite; cement calcareous or marly. Rock more friable than preceding. (Molasse, p. 93.)

§ 8. Non-coherent Rocks, with Essential Elements Isolated.

Minute grains of Quartz. (Quartz Sand, p. 93.

Quartz grains with flakes of Mica. (Micaceous Sand.)

Quartz Sand is often mixed with fragments of Garnets, Zircons, Magnetite, etc.

Sand formed of small grains and pebbles of Quartz, Jasper, or Flint (Gravel.)

Pulverulent material or very fine fragments of Trachyte or Pumice. (Trachytic Cinder, p. 27.)

Basaltic rocks equally pulverized, or débris of Volcanic Scoria. (Volcanic Ashes, Lapilli and Puzzulana, p. 59.)

Sand is sometimes formed of grains of Dolomite soluble in hot acids, and giving reactions of Lime and Magnesia (p. 104.)

PART FOURTH.

APPENDIX.

DICHOTOMIC METHOD FOR THE DETERMINATION OF ROCKS.*

1	The rock appears homogeneous. 2.	
	It is evidently heterogeneous. 175.	
2	It has a metallic aspect, not removed by scratching with a steel point. 3.	
	Has a non-metallic appearance, or a metallic lustre easily removed by action of steel point. 9.	
3	On charcoal before the blow-pipe yields sulphurous odor. 4.	
	On charcoal does not yield sulphurous odor. 8.	
4	Yields a metallic globule, malleable.	*Galena.*
	Yields a non-metallic globule. 5.	
5	The solution of the globule in nitric acid, becomes blue with Ammonia.	*Chalco-pyrites.*
	The nitric acid solution does not become blue. 6.	
6	The rock has a bronze color.	*Magnetic Pyrites.*
	It is of a brass-yellow color. 7.	
7	It is of compact structure.	*Compact Pyrites.*
	It is radiated.	*Fibrous Pyrites.*
8	The rock is compact.	*Compact Magnetite.*
	It is granular.	*Granular Magnetite.*
9	Nitric acid produces effervescence. 10.	
	Does not. 38.	
10	The effervescence is abundant. 11.	
	Effervescence slow or requiring heat. 25.	
11	The solution in acid leaves much residue. 12.	
	Leaves but little residue. 17.	

*Translated from "Cours Elementaire de Geologie Appliquée," par M. Stanislas Meunier.

12	The residue is black, consisting of carbon. 13.	
	It is not black. 14.	
13	Heated in closed tube yields bitumen.	*Bituminous Limestone.*
	Yields no bitumen.	*Anthraconite.*
14	The residue consists of grains harder than glass.	*Calcareous Schist.*
	It is of soft material. 15.	
15	The residue forms a paste with water. 16.	
	Does not form a paste.	*Marly Limestone.*
16	The rock is compact.	*Marlstone.*
	It is schistose.	*Marl-Shale.*
17	The rock is soluble in water.	*Natron.*
	Insoluble. 18.	
18	The rock is not coherent.	*Calcareous Sand.*
	It is coherent. 19.	
19	The rock consists of pebbles or fragments cemented together.	*Calcareous Pudding Stone or Breccia.*
	It does not consist of cemented fragments. 20.	
20	The rock is crystalline. 21.	
	It is not crystalline. 22.	
21	The rock is granular.	*Granular Limestone.*
	The rock is fibrous.	*Fibrous Limestone.*
22	The rock is friable.	*Earthy Limestone.*
	It is not friable. 23.	
23	The rock is formed of organic remains.	*Fossil Limestone.*
	Is not so formed. 24.	
24	The rock is compact.	*Compact Limestone.*
	It is globuliferous.	*Oolitic Limestone.*
25	It is fusible before the blow-pipe. 26.	
	It is infusible. 50.	
26	It yields by fusion a white enamel. 27.	
	Fuses to a black magnetic bead. 28.	
27	It is crystalline.	*Crystalline Calamine.*
	It is compact.	*Compact Calamine.*

28	It is crystalline.	*Spathic Siderite.*
	Is not crystalline. 29.	
29	It is compact.	*Compact Siderite.*
	It is schistose.	*Schistose Siderite.*
30	Gives magnesia reaction with Cobalt. 31.	
	No magnesia reaction; effervescence due to impurities. 38.	
31	The acid solution of No. 9 is precipitated by ammonium oxalate and heat. 32.	
	No such reaction. 36.	
32	The rock is incoherent.	*Sandy Dolomite.*
	The rock is coherent. 33.	
33	The rock is crystalline.	*Granular Dolomite.*
	It is not crystalline. 34.	
34	The rock is schistose.	*Schistose Dolomite.*
	It is compact. 35.	
35	The rock is firm and solid.	*Compact Dolomite.*
	It is pulverulent.	*Earthy Dolomite.*
36	The rock is crystalline. 37.	
	Is not crystalline.	*Compact Giobertite.*
37	The rock is laminated.	*Spathic Giobertite.*
	It is granular.	*Granular Giobertite.*
38	Heated in closed tube yields condensable vapors. 39.	
	Yields no condensable products. 103.	
39	The condensed vapor is water. 58.	
	The condensed vapor is not water. 40.	
40	Heated in open air, it fuses and burns with blue flame. 41.	
	Burns, but not with *blue* flame. 43.	
41	The rock is crystalline.	*Sulphur.*
	Is not crystalline. 42.	
42	It is compact.	*Compact Sulphur.*
	It is porous.	*Tufaceous Sulphur.*
43	It is liquid.	*Petroleum.*
	Is not liquid. 44.	
44	It fuses completely in closed tube. 45.	
	Does not fuse. 46.	

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45	It is solid.	*Asphalt.*
	It is pasty or viscid.	*Pisasphalt.*
46	Burns easily and with flame. 49.	
	Burns with difficulty and without flame. 47.	
47	The rock is pulverulent	*Earthy Anthracite.*
	Is not so. 48.	
48	It is compact.	*Compact Anthracite.*
	It is schistose.	*Schistose Anthracite.*
49	The powder of the rock is black. 50.	
	It is brown. 52.	
50	The rock is pulverulent.	*Earthy Bituminous Coal.*
	It is not. 51.	
51	It is compact.	*Compact Bituminous Coal.*
	It is schistose.	*Schistose Bituminous Coal.*
52	It is schistose. 53.	
	Is not schistose. 54.	
53	It is sonorous.	*Naphto-schist.*
	Is not.	*Lignite.*
54	It is compact. 55.	
	Is not compact. 56.	
55	Burns, yielding odor of bitumen.	*Compact Lignite.*
	Burns, giving odor of dry herbs.	*Peat.*
56	It is earthy.	*Earthy Lignite.*
	Exhibits woody structure. 57.	
57	Exhibits fibre of wood.	*Wood Lignite.*
	Exhibits structure of small plants.	*Fibrous Peat.*
58	It is infusible before the blow-pipe. 59.	
	It is fusible. 73.	
59	It is black and will mark on paper. 60.	
	Will not make a mark. 61.	
60	It is pulverulent.	*Pulverulent Manganite.*
	Is not pulverulent.	*Compact Manganite.*
61	Before the blow-pipe gives the Alumina reaction. 62.	
	Does not give Alumina reaction. 66.	
62	It is globuliferous.	*Oolitic Bauxite.*
	Is not globuliferous. 63.	

63	It is a pudding stone or breccia.	*Conglomerate Jasper.*
	It is not. 64.	
64	It is quite solid.	*Compact Jasper.*
	It has but little solidity. 65.	
65	It forms a paste with water.	*Compact Clay.*
	Does not form paste.	*Compact Bauxite.*
66	It is quite friable or even pulverulent. 67.	
	It is quite coherent. 68.	
67	Under the microscope, it exhibits skeletons of infusoria	*Tripoli.*
	Under the microscope, appears amorphous.	*Kieselguhi Menilite.*
68	The rock is porous.	*Geyserite.*
	It is compact. 69.	
69	It gives blow-pipe reactions for Magnesia. 70.	
	Does not.	*Compact Opal.*
70	It has a schistose structure. 71.	
	Has not. 72.	
71	The laminæ have an unctuous feel.	*Talcose Schist.*
	The laminæ are not unctuous.	*Schistoidal Serpentine.*
72	The rock is a conglomerate.	*Serpentine Breccia.*
	Is not.	*Compact Serpentine.*
73	Fuses to a magnetic bead. 74.	
	The bead is not magnetic. 78.	
74	The powder of the rock is yellow. 75.	
	The powder is blue-black. 77.	
75	It is globuliferous.	*Globuliferous Limonite.*
	It is uniform. 76.	
76	It is pulverulent.	*Earthy Limonite.*
	It is compact.	*Brown Hematite.*
77	It is compact.	*Compact Chamoisite.*
	It is oolitic.	*Oolitic Chamoisite.*
78	It gives before the blow-pipe magnesia reactions. 79.	
	Does not. 80.	
79	It is compact.	*Compact Magnesite.*
	It is schistose.	*Magnesite Schist.*
80	It is black and may be used as a slate-pencil. 81.	
	Is not. 82.	

81 { It is pulverulent. *Earthy Ampelite.*
It is schistoidal. *Ampelite Schist.*

82 { It is schistose. 83.
It is not. 87.

83 { It forms a paste with water. *Argillaceous Shale.*
Does not. 84.

84 { The rock is green. *Chlorite Schist.*
Is not green. 85.

85 { Fuses to a white enamel spotted with black. *Phonolite Schist.*
Fused mass has not this appearance. 86.

86 { The rock is formed of thin laminæ. *Clay Slate.*
Not formed of very thin laminæ. *Argillaceous Schist.*

87 { It forms a paste with water. 88.
Does not. 90.

88 { It is compact. *Compact Clay.*
Is not compact. 89.

89 { It is oolitic. *Oolitic Clay.*
It is white and pulverulent. *Kaolin.*

90 { Calcination renders it partially soluble. 91.
Not thus made soluble in water. 95.

91 { The rock is a conglomerate. *Alunite Breccia.*
Is not. 92.

92 { It is compact. *Compact Alunite.*
It is earthy. *Earthy Alunite.*

93 { It is green. 94.
Is not green. 95.

94 { It is compact. *Compact Glauconite.*
It is oolitic. *Oolitic Glauconite.*

95 { It may be scratched by the thumb nail. 96.
Cannot be. 100.

96 { Has a clayey appearance. 97.
Is compact and stone like. 98.

97 { It falls to pieces in water but does not form a paste. *Loam.*
Does not disintegrate in water. *Clay.*

98 { It is compact. *Compact Gypsum.*
It is crystalline. 99.

99	It is fibrous.	*Fibrous Gypsum.*
	It is granular.	*Granular Gypsum.*
100	It fuses to a white enamel with black spots. 101.	
	The fused product has not such appearance. 102.	
101	The rock is clear and gray.	*Compact Leucostite.*
	It is dark colored.	*Compact Phonolite.*
102	It has a vitreous lustre.	*Perlite.*
	Has not.	*Compact Slate.*
103	It is fusible before the blow-pipe. 104.	
	It is infusible. 101.	
104	It is soluble in water and consequently deliquescent. 105.	
	Not soluble in water. 109.	
105	It fuses on a red hot coal.	*Nitratine.*
	Does not. 106.	
106	It colors blow-pipe flame bright yellow. 107.	
	Does not.	*Carnallite.*
107	It is fibrous.	*Fibrous Rock Salt.*
	Is not fibrous. 108.	
108	It is compact.	*Compact Rock Salt.*
	It is granular.	*Granular Rock Salt.*
109	It gives when heated upon charcoal a sulphurous odor. 110.	
	Does not. 116.	
110	The rock is of remarkably high density. 111.	
	Density is not remarkable. 114.	
111	It colors the blow-pipe flame deep red. 112.	
	Does not. 113.	
112	It is compact.	*Compact Celestine.*
	It is crystalline.	*Crystalline Celestine.*
113	It is compact.	*Compact Heavy Spar.*
	It is crystalline.	*Crystalline Heavy Spar.*
114	The rock is a conglomerate.	*Anhydrite Breccia.*
	It is not. 115.	
115	It is compact.	*Compact Anhydrite.*
	It is granular.	*Granular Anhydrite.*
116	Treated with sulphuric acid in the closed tube, it attacks the glass.	*Fluor Spar.*
	Does not. 117.	

117	It has a metallic lustre which disappears in a scratch. 118.	
	Has no metallic lustre. 119.	
118	Fuses to a magnetic globule.	*Hematite.*
	Does not yield a magnetic globule.	*Mica.*
119	The rock is earthy. 121.	
	Is not. 124.	
120	It fuses to a magnetic globule. 121.	
	Fusion does not yield a magnetic globule. 122.	
121	The rock is magnetic.	*Magnetite.*
	Is not.	*Red Hematite.*
122	Fuses to a white enamel.	*Pumice.*
	Does not fuse to an enamel entirely white. 125.	
123	The rock is black.	*Earthy Basalt.*
	Is not black.	*Wacke.*
124	The product of fusion is quite white. 125.	
	Is not white. 136.	
125	It fuses with great difficulty. 126.	
	Fuses easily. 127.	
126	It is granular.	*Apatite.*
	It is compact.	*Thorphorite.*
127	It is attacked by acids. 128.	
	Is not. 130.	
128	It is crystalline.	*Labradorite.*
	Is not. 129.	
129	The rock is compact.	*Saussurite.*
	It is scoriaceous.	*Tephrine.*
130	The rock is vitreous. 131.	
	It is not. 134.	
131	It has a conchoidal fracture.	*Obsidian.*
	Fracture is rough or granular. 132.	
132	The rock is very light.	*Pumice.*
	Is not. 133.	
133	It has a resinous aspect.	*Retinite.*
	Has not.	*Vitreous Trachyte.*
134	It is porous and rough.	*Trachyte.*
	Is not porous. 135.	
135	It is granular.	*Leptynite.*
	It is compact.	*Eurite or Petrosilex.*

136 { It is magnetic. 137.
Is not. 139.

137 { The rock is compact. *Compact Hematite.*
Is not. 138.

138 { It is fibrous. *Fibrous Hematite.*
It is globuliferous. *Oolitic Hematite.*

139 { The rock is vitreous. *Gallinace* (Vitreous Basalt).
It is not. 140.

140 { It is compact. 141.
Is not. 150.

141 { It is green or greenish. 142.
Is not. 144.

142 { It gives magnesia reactions before the blow-pipe. *Lherzolyte* (Pyroxene Rock).
Gives no magnesia reactions. 143.

143 { It is of a light clear green color. *Epidote.*
It is of a deep green color. *Keralite* (*Minette*).

144 { It is of a reddish or yellowish color. *Garnet Rock.*
It is black or blackish. 145.

145 { The product of fusion is entirely black. 146.
Is not quite black. 148.

146 { The rock affects the magnetic needle. *Basalt.*
Does not. 147.

147 { It gives alumina reactions before the blow-pipe. *Compact Aphanite.*
Does not. *Amphibolite.*

148 { The rock exhibits a horny lustre. 149.
Has not this lustre. *Leptynolite.*

149 { Contains mica which may be recognized by aid of a lens. *Keralite.*
Has no trace of mica. *Hornstone.*

150 { It is granular. 151.
Is not granular. 155.

151 { It is green. 153.
It is reddish or black. 152.

152 { It is reddish. 154.
It is black. *Hornblende Rock.*

153 { It gives alumina reactions. *Granular Epidote.*
It gives magnesia reactions. *Pyroxene.*

154	It gives magnesia reactions.	*Lherzolite.*
	Does not.	*Garnet.*
155	The rock is schistose. 156.	
	Is not schistose. 157.	
156	It contains no mica.	*Hornblende Rock.*
	Contains mica.	*Leptynolite.*
157	It is scoriaceous. 158.	
	Is not scoriaceous. 159.	
158	It is black.	*Scoriaceous Basalt.*
	It is brown.	*Basanite* (Altered Phonolite).
159	It appears formed of fragments. 160.	
	It is globuliferous; its color is greenish.	*Variolite.*
160	It is black.	*Basalt.*
	It is of a clear color.	*Lherzolite.*
161	It will scratch glass. 162.	
	Will not. 170.	
162	It is compact. 163.	
	Is not. 166.	
163	It is opaque, even at thin edges. 164.	
	It is translucent at thin edges. 165.	
164	It is of a black color.	*Phtanite* (Jasper).
	Is not black.	*Compact Jasper.*
165	It has a vitreous fracture.	*Crystalline Quartz.*
	The fracture is smooth or waxy.	*Compact Quartz.*
166	It is a breccia. 167.	
	It is not. 168.	
167	The fragments are opaque at thin edges.	*Jasper Breccia.*
	Thin edges are translucent.	*Quartz Breccia.*
168	The rock is porous.	*Millstone.*
	It is not. 169.	
169	It is coherent.	*Quartzite Sandstone.*
	Is not coherent.	*Sand.*
170	The rock is quite black. 171.	
	Is not. 173.	
171	It gives manganese reactions before the blow-pipe. 172.	
	Does not.	*Graphite.*

172	It is compact.	*Compact Pyrolusite.*
	It is pulverulent.	*Earthy Pyrolusite.*
173	It dissolves in nitric acid, depositing sulphur.	*Blende.*
	Does not give this reaction. 174.	
174	It is compact.	*Compact Diallogite.*
	It is granular.	*Granular Diallogite.*
175	The rock is entirely formed of crystals. 176.	
	Not entirely so. 228.	
176	It exhibits only two substances. 195.	
	It exhibits more than two. 177.	
177	Four different substances may be distinguished. 178.	
	Only three minerals can be seen. 179.	
178	One of the minerals is amphibole.	*Syenite.*
	Amphibole is not present.	*Granitite.*
179	Mica is one of the elements. 180.	
	Mica is not. 187.	
180	The rock contains quartz. 181.	
	Contains no quartz.	*Monzonite.*[*]
181	The mica is replaced by talc. 182.	
	Is not. 185.	
182	The rock is foliated.	*Protogine Schist.*
	It is not foliated. 183.	
183	It is granitoid in character.	*Granitoid Protogine.*
	It is pseudo-porphyritic. 184.	
184	The disseminated fragments are feldspar crystals.	*Porphyritic Protogine.*
	The fragments are rounded.	*Glandular Protogine.*
185	The rock is schistose.	*Gneissic Granite.*
	Is not. 186.	
186	It is porphyritic.	*Porphyritic Granite.*
	It is granular.	*Common Granite.*
187	The rock contains quartz.	*Luxuliane.*[†]
	It contains no quartz. 188.	
188	The rock is of a greenish color. 189.	
	Is not. 190.	

[*] Contains Feldspar, Mica and Pyroxene. One of the Wackes.

[†] Quartz, feldspar and tourmaline.

189	It contains talcose materials.	*Eupholite.**
	Contains no talc, but green earthy particles.	*Ophitone.*†
190	It contains hornblende. 191.	
	It contains augite. 193.	
191	Contains zircon (brown or reddish). 192.	
	No zircon present.	*Leucite Rock.*
192	It is granular.	*Zircon Syenite.*
	It is porphyritic.	*Porphyritic Zircon Syenite.*
193	The rock contains a white or whitish mineral. 194.	
	Contains no such mineral.	*Peridotite.*
194	The white mineral yields considerable water in the closed tube.	*Analcymite.*
	Does not yield sensible quantity of water.	*Nephelinite.*
195	The rock effervesces much with acids. 196.	
	Effervescence is not abundant. 199.	
196	It contains a green mineral.	*Ophicalcite.*
	Does not. 197.	
197	Mica is easily distinguished.	*Cipollino.*
	No Mica to be seen. 198.	
193	It contains talc.	*Ophicalcite* or *Talc Schist.*
	It contains hornblende.	*Hemitrene.*
199	It contains quartz. 200.	
	Contains no quartz. 206.	
200	The structure is schistose. 201.	
	It is granular. 204.	
201	Mica is one of the essential elements. 202.	
	Talc is one of the essential elements. 203.	
202	The rock laminæ are porphyritic.	*Porphyritic Mica Schist.*
	Are not porphyritic.	*Mica Schist* proper.
203	The rock laminæ have a porphyritic structure.	*Porphyritic Talcose Schist.*
	Are not porphyritic.	*Talcose Schist.*
204	The rock contains a brilliant black mineral.	*Schorl Rock.*
	Contains no black mineral. 205.	
205	Mica is an essential element.	*Greisen.*
	Is not.	*Granulite.*

*Euphotide with Talc.

† Calcite, Mica, Epidote.

206	Mica is an essential element. 207.	
	Is not. 211.	
207	The rock is schistose. 208.	
	Is not. 209.	
203	The layers have a porphyritic structure.	*Porphyritic Gneiss.*
	Have not.	*Common Gneiss.*
209	One mineral other than mica is gray and rough.	*Micaceous Trachyte.*
	This mineral has not these properties. 210.	
210	The mica is brown.	*Minette.*
	The mica is not brown.	*Kersanton.*
211	The rock contains talc. 212.	
	Contains no talc. 214.	
212	The structure is schistoidal.	*Dolerine* Schist.*
	Is not schistoid. 213.	
213	It is granular.	*Granular Dolerine.*
	It is porphyroidal.	*Porphyroidal Dolerine.*
214	The rock contains amphibole in sensible quantity. 215.	
	Contains no amphibole. 221.	
215	It has a trachytic aspect. 216.	
	Aspect is not trachytic. 217.	
216	The mineral other than amphibole is attacked by acids.	*Hornblende Andesite.*
	This mineral not attacked by acids.	*Hornblende Trachyte.*
217	The mineral other than hornblende is orthoclase. 218.	
	It is not orthoclase. 219.	
218	The rock is granular.	*Granular Syenite.*
	It is porphyritic.	*Porphyritic Syenite.*
219	The rock is schistose.	*Diorite Schist.*
	Is not. 220.	
220	The rock is granular.	*Granular Diorite.*
	It is porphyritic.	*Porphyritic Syenite.*
221	At least one of the minerals is green or yellow. 222.	
	Neither of them is green or yellow. 225.	
222	The other mineral is black with a metallic lustre.	*Dunite.*
	It is neither black nor metallic. 223.	
223	It is red or reddish.	*Eclogite.*
	Neither red nor reddish. 224.	

*A form of Talc Schist containing Chlorite.

224 It is orthoclase recognized by its cleavage. *Diabasite.*
Is not orthoclase. Euphotide.

225 The rock is a mixture of a white and a black mineral. 226.
It is a mixture of a white and a brown mineral. 227.

226 Its structure is granular. *Granular Dolerite.*
It is scoriaceous. *Scoriaceous Dolerite.*

227 The brown mineral is diallage; infusible. *Granitone.*
It is hypersthene, fusible to a gray enamel. *Hyperite.*

228 The rock is composed of fragments united by a cement. 229.
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229 The fragments are crystals. 230.
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235 The rock contains quartz. *Quartz-Porphyry Schist.*
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238 The mineral appears in crystals forming crosses. *Staurolite.*
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Is not of this character. *Andalusite Schist.*

240 It effervesces with acids. 241.
Does not. 242.

241 It contains mica. *Porphyritic Cipollino or Micalcite.*
Does not. *Porphyritic Hemitrene.*

242 { The rock contains mica or talc. 243.
Does not. 245.

243 { The paste or cement is rough. *Micaceous Trachyte.*
Is not rough. 244.

244 { The foliated mineral is green and unctuous (Talc). *Porphyritic Protogine.*
Is not. *Porphyritic Granite.*

245 { The rock contains quartz. 246.
Does not. 249.

246 { The disseminated grains are quartz. *Graphic Pegmatite.*
They are not quartz., 247.

247 { The cementing material feels rough. *Quartz Trachyte.*
Is not rough.

248 { It becomes partially soluble by calcination. *Porphyritic Alunite.*
Does not become soluble. *Quartziferous Porphyry.*

249 { The matrix has a vitreous aspect. 250.
Has not. 251.

250 { The fracture is conchoidal. *Por. Obsidian.*
Is not. *Por. Retinite.*

251 { The matrix becomes partially soluble by calcination. *Por. Alunite.*
Does not. 252.

252 { It gives reactions for alumina. *Por. Clay Schist.*
Does not. 253.

253 { The paste or matrix is infusible. *Serpentine Breccia.*
It is fusible. 254.

254 { The paste fuses to a black enamel. 255.
It fuses to a white enamel. 259.

255 { It is of an ash-gray color. 256.
Is not. 258.

256 { It has an argillaceous appearance. *Wacke or Wackite.*
Aspect is not argillaceous. 257.

257 { The contained minerals reduce to a gelatinous mass in H Cl. *Por. Nephelinite.*
Does not. *Por. Amphigenite.*

258 { The cemented materials form a jelly in HCl. *Basalt* with *Peridot.*
Do not. *Melaphyre.*

259 { The cemented mineral is pyroxene. *Por. Dolerite.*
Is not pyroxene. 260.

260	It is hornblende. 261. Is not. 262.	
261	The matrix is orthoclase. Is not orthoclase.	*Por. Syenite.* *Por. Diorite.*
262	The matrix or cement is rough to the touch. Is not rough. 263.	*Por. Trachyte.*
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271	The paste presents an argillaceous aspect. 272. Does not. 275.	
272	It is infusible. It is fusible. 273.	*Globuliferous Bauxite.*
273	Fuses to a magnetic mass. 274. Product of fusion is not magnetic.	*Amygdaloid Wackite.*
274	The powder of the paste is red. The powder of the paste is yellow.	*Oolitic Hematite.* *Oolitic Limonite.*
275	The rock is fusible to a white enamel. 276. Fuses to a black enamel. 279.	
276	The lustre is vitreous. 277. Lustre is not vitreous. 278.	
277	It presents a conchoidal fracture. Fracture is not conchoidal.	*Glob. Obsidian.* *Glob. Perlite.*

278 { The rock contains quartz. *Pyromeride.*
Contains no quartz. *Stigmite* (Retinite).

279 { The nodules have the same aspect as the paste. *Orbicular Diorite.*
Have a different aspect. 280.

280 { The rock is greenish. *Variolite.*
Is not. 281.

281 { The paste is quite black. *Amygdaloid Basalt.*
Is not. 282.

282 { Pyroxene crystals may be distinguished. *Amygdaloid Diorite.*
Not recognized. *Spilite.*

283 { The rock has an arenaceous structure. 284.
It is a breccia or pudding stone. 296.

284 { Two minerals only may be recognized, one being quartz. 287.
More than two minerals are recognized. 285.

285 { Fragments of slates and schists are seen. *Polygenic Sandstone.*
Such fragments not seen. 286.

286 { Grains occur which are hard, white, and fusible. *Micaceous Arkose.*
No hard grains which are fusible. *Micaceous Psammite.*

287 { The rock effervesces with acids. 288.
Does not effervesce. 289.

288 { Dissolved in acid, the rock leaves a residue of quartz only. *Calcareous Sandstone.*
The residue after solution contains clay. *Molasse.*

289 { The rock is magnetic. 290.
Is not. 291.

290 { It is schistose. *Emery Schist.*
It is granular. *Granular Emery.*

291 { The rock contains grains which fuse to a magnetic bead. 292.
Contains no such grains. 293.

292 { The rock is a schist. *Itabirite Schist.*
It is granular. *Granular Itabirite.*

293 { The grains (not quartz) are quite hard and fuse to a white bead. *Arkose.*
These grains are not hard. 294.

294 { They are quite white and friable. *Metaxite* (an argillaceous sandstone.)
Are not. 295.

295 { The rock is mostly of quartz grains; some mica. *Psammite.*
Quartz grains with small particles of slate. *Traumate.*

296 { The fragments are of more than two kinds. 297.
Only two kinds at most. 298.

297 { The fragments are angular. *Breccia.*
They are rounded. *Puddingstone.*

298 { The rock effervesces with acids. 299.
Does not. 305.

299 { The rock contains a green material. 300.
Does not. 301.

300 { The rock is crystalline. *Ophicalcite Breccia.*
It is compact. *Albereze* (Ruin Marble).

301 { It contains talc. *Cipollino* or *Ophicalcite.*
Does not. 302.

302 { Dissolves in dilute acid, leaving an abundant earthy residue. 304.
Residue not abundant. 303.

303 { Fragments are angular. *Calcareous Breccia.*
Fragments are rounded. *Cal. Puddingstone.*

304 { The residue is infusible. *Albereze* (See 300).
The residue is fusible. *Slaty Limestone.*

305 { It gives magnesia reactions. 306.
Does not. 307.

306 { Heated in tube yields water. *Serpentine Breccia.*
Yields no water. *Lherzolite Breccia.*

307 { After calcination is soluble in water. *Alunite Breccia.*
Is not. 308.

308 { The rock is infusible before the blow-pipe. 309.
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309 { It is translucent at thin edges. 310.
It is opaque even at thin edges. 311.

310 { The fragments are angular. *Quartz Breccia.*
The fragments are rounded. *Quartz Puddingstone.*

311 { The fragments are angular. *Jasper Breccia.*
The fragments are rounded. *Jasper Puddingstone.*

312 { The product of fusion is magnetic. *Limonite Breccia.*
Is not. 313.

313 { The rock heated on charcoal gives a sulphurous odor. *Anhydrite.*
Does not. 314.

314	The product of fusion is black. 315.	
	The product of fusion is white. 317.	
315	Some fragments are quite hard and black. 316.	
	Most of the fragments are soft and brownish.	*Peperino.*
316	All the fragments are black.	*Basalt Conglomerate.*
	Some are bottle-green or reddish.	*Basalt with Peridot.*
317	The fragments are rough to the touch. 318.	
	Are not rough. 319.	
318	They are very light.	*Pumice Conglomerate.*
	Are not.	*Trachyte Conglomerate.*
319	The rock is vitreous.	*Obsidian Conglomerate.*
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